

CREW SYSTEMS LABORATORY

BUILDING 7

HISTORICAL DOCUMENTATION

Prepared for:

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

Prepared by:

Archaeological Consultants, Inc.
Sarasota, Florida

May 2010

PREFACE

In response to President George W. Bush's announcement in January 2004 that the Space Shuttle program (SSP) would end in 2010, the National Aeronautics and Space Administration (NASA) completed a nation-wide historical survey and evaluation of NASA-owned facilities and properties (real property assets) at all its Centers and component facilities. The buildings and structures which supported the SSP were inventoried and assessed as per the criteria of eligibility for listing in the National Register of Historic Places (NRHP) in the context of this program. This study was performed in compliance with Section 110 of the National Historic Preservation Act (NHPA) of 1966 (Public Law 89-665), as amended; the National Environmental Policy Act (NEPA) of 1969 (Public Law 91-190); Executive Order (EO) 11593: Protection and Enhancement of the Cultural Environment; EO 13287, Preserve America, and other relevant legislation.

As part of this nation-wide study, in September 2006, historical survey and evaluation of NASA-owned and managed facilities was conducted by NASA's Lyndon B. Johnson Space Center (JSC) in Houston, Texas. The results of this study are presented in a report entitled, "Survey and Evaluation of NASA-owned Historic Facilities and Properties in the Context of the U.S. Space Shuttle Program, Lyndon B. Johnson Space Center, Houston, Texas," prepared in November 2007 by NASA JSC's contractor, Archaeological Consultants, Inc. (ACI). As a result of this survey, the Crew Systems Laboratory (CSL; Building 7) was evaluated by NASA JSC as eligible for listing in the NRHP, with concurrence by the Texas State Historic Preservation Officer (SHPO). Building 7 is considered eligible under NRHP Criteria A and C in the context of the U.S. Space Shuttle program (1969-2010). Because it has achieved significance within the past 50 years, Criteria Consideration G applies.

Building 7 is currently in active use in support of the SSP. This documentation package was prepared, proactively, to mitigate, at least in part, the adverse effects of future facility modifications, in accordance with Section 106 of the NHPA, as amended, and the implementing regulations, 36 CFR Part 800. It includes a historical summary of the Space Shuttle program; the history of JSC in relation to the SSP; a narrative of the history of Building 7 and how it supported the SSP; and a physical description of the historic property. In addition, photographs documenting the construction and historical use of Building 7 in support of the SSP, as well as photographs of the facility documenting the existing conditions, special technological features, and engineering details, are included. A contact sheet printed on archival paper, and an electronic copy of the work product on CD, are also provided.

ACKNOWLEDGEMENTS

Archaeological Consultants, Inc. (ACI) extends its gratitude to Perri E. Fox, NASA JSC's Shuttle Transition Manager, and Sandra J. Tetley, NASA JSC's Real Property Officer and Historic Preservation Officer (HPO), for making all arrangements for access and information gathering in support of this documentation effort. We also thank the staff of the JSC Imagery Repository for their cooperation in providing historical photographs; and the staff of the Engineering Drawing Control Center for their cooperation in providing architectural drawings of the facility. We deeply appreciate the efforts of Mary P. Cerimele, Building 7 Chambers Manager, for serving as ACI's facility point of contact and for providing valuable information on the historical and current uses of the Environmental Test Area within the facility in support of the Space Shuttle program. Scott Stratton is also thanked for sharing his knowledge of spacesuit testing procedures in the CSL vacuum chambers. The personal experiences of former managers and engineers, shared in the oral histories created by Rebecca Wright and Jennifer Ross-Nazzal, Tessada & Associates, added dimension to the story of Building 7.

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**CREW SYSTEMS LABORATORY
BUILDING 7
JOHNSON SPACE CENTER
HOUSTON, TEXAS**

Basic Information

Location: At the southern terminus of Fourth Street
Johnson Space Center
Houston
Harris County
Texas

U.S.G.S. 7.5 minute League City, Texas, quadrangle,
Universal Transverse Mercator coordinates:
15.297905.3271571

Date of Construction: 1962-1964

Architect/Engineer: Brown & Root, Inc., in association with Charles Luckman Associates (planning and design consultants); Brooks & Barr, Harvin C. Moore, MacKie & Kamrath, and Wirtz Calhoun Tungate & Jackson (architects)

Bernard Johnson & Associates (mechanical engineers)

Builder: C.H. Leavell and Company, Morrison-Knudsen Construction Company, and Paul Hardeman

Present Owner: National Aeronautics and Space Administration, Johnson Space Center, Houston, Texas

Present Use: Testing of spacecraft life support systems used on the Space Shuttle orbiter vehicle

Significance: The Crew Systems Laboratory (Building 7) is considered eligible for listing in the National Register of Historic Places (NRHP) in the context of the U.S. Space Shuttle program (1969-2010) under Criterion A in the area of Space Exploration and under Criterion C in the area of Engineering. Because it has achieved significance within the past 50 years, Criteria Consideration G applies. Under Criterion A, Building 7 is significant as the performance testing site for all primary life support system equipment,

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including spacesuits and backpacks, critical to the health and safety of Space Shuttle mission crew members. This facility also plays a key role in maintaining the habitable environment of the Orbiter, and in supporting astronaut training in EVA suit-up procedures. Under Criterion C, the vacuum chambers, which simulate the extreme environment of space, have contributed significantly to the Space Shuttle program by providing valuable engineering data on the long-term performance of Shuttle spacesuits and other equipment needed for long duration missions. Although there have been minor modifications to the Crew Systems Laboratory, these have enhanced the building's capability to perform its functions. Thus, the facility maintains its integrity of location, design, setting, materials, workmanship, feeling, and association.

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The U.S. Space Shuttle Program

On January 5, 1972, President Nixon delivered a speech in which he outlined the end of the Apollo era and the future of a reusable space flight vehicle, the Space Shuttle, which would provide “routine access to space.” By commencing work at this time, Nixon added, “we can have the Shuttle in manned flight by 1978, and operational a short time after that.”¹ The Space Task Group (STG), previously established by President Nixon in February 1969 to recommend a future course for the U.S. Space Program, presented three choices of long-range plans. All included an Earth-orbiting space station, a space shuttle, and a manned Mars expedition.² Although none of the original programs presented was eventually selected, the National Aeronautics and Space Administration (NASA) implemented a program, shaped by the politics and economic realities of the time, which served as a first step toward any future plans for implementing a space station.³

On January 5, 1972, President Richard Nixon instructed NASA to proceed with the design and building of a partially reusable space shuttle consisting of a reusable orbiter, three reusable main engines, two reusable solid rocket boosters (SRBs), and one non-reusable external liquid fuel tank (ET). NASA’s administrators vowed that the shuttle would fly at least fifty times a year, making space travel economical and safe. NASA gave responsibility for developing the shuttle orbiter vehicle and overall management of the Space Shuttle program (SSP) to the Manned Space Center (MSC, now the Johnson Space Center [JSC]) in Houston, based on the Center’s experience. The Marshall Space Flight Center (MSFC) in Huntsville, Alabama, was responsible for development of the Space Shuttle Main Engine (SSME), SRBs, the ET, and for all propulsion-related tasks. Engineering design support continued at MSC, MSFC and NASA’s Langley Research Center (LaRC), in Virginia, and engine tests were to be performed at NASA’s Mississippi National Space Technology Laboratories (NSTL, later named Stennis Space Center [SSC]) and at the Air Force’s Rocket Propulsion Laboratory in California, which later became the Santa Susana Field Laboratory (SSFL).⁴ NASA selected the Kennedy Space Center (KSC) in Florida, as the primary launch and landing site for the SSP. KSC, responsible for designing the launch and recovery facilities, was to develop methods for shuttle assembly, checkout, and launch operations.⁵

On September 17, 1976, the full-scale orbiter prototype, *Enterprise* (OV- 101), was completed. Designed for test purposes only and never intended for space flight, structural assembly of this

¹ Marcus Lindroos. “President Nixon’s 1972 Announcement on the Space Shuttle.” (NASA Office of Policy and Plans, NASA History Office, updated April 14, 2000).

² NASA, History Office, NASA Headquarters. “Report of the Space Task Group, 1969.”

³ Dennis R. Jenkins. *Space Shuttle, The History of the National Space Transportation System. The First 100 Missions.* (Cape Canaveral, Florida: Specialty Press, 2001), 99.

⁴ Jenkins, 122.

⁵ Linda Neuman Ezell. *NASA Historical Databook Volume III Programs and Projects 1969-1978.* The NASA History Series, NASA SP-4012, (Washington, D.C.: NASA History Office, 1988), Table 2-57; Ray A. Williamson. “Developing the Space Shuttle.” *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume IV: Accessing Space.* (Edited by John M. Logsdon. Washington, D.C.: U.S. Printing Office, 1999), 172-174.

orbiter had started more than two years earlier in June 1974 at Air Force Plant (AFP) 42 in Palmdale, California. Although the *Enterprise* was an aluminum shell prototype incapable of space flight, it reflected the overall design of the orbiter. As such, it served successfully in 1977 as the test article during the Approach and Landing Tests (ALT) aimed at checking out both the mating with the shuttle carrier aircraft (SCA) for ferry operations, as well as the orbiter's unpowered landing capabilities.

The first orbiter intended for space flight, *Columbia* (OV-102), arrived at KSC from the shuttle assembly facility in Palmdale in March 1979. Originally scheduled to lift off in late 1979, the launch date was delayed by problems with both the SSME components, as well as the thermal protection system (TPS). *Columbia* spent 610 days in the Orbiter Processing Facility (OPF), another thirty-five days in the Vehicle Assembly Building (VAB), and 105 days on Pad 39A before finally lifting off on April 12, 1981. STS-1, the first orbital test flight and first Space Shuttle program mission, ended with a landing on April 14 at Edwards Air Force Base (AFB) in California. This launch demonstrated *Columbia*'s ability to fly into orbit, conduct on-orbit operations, and return safely.⁶ *Columbia* flew three additional test flights in 1981 and 1982, all with a crew of two. The Orbital Test Flight Program ended in July 1982 with 95% of its objectives completed. After the end of the fourth mission, President Ronald Reagan declared that with the next flight the Shuttle would be "fully operational."

A total of 129 Space Shuttle missions have been launched from the KSC between April 1981 and December 2009. From April 1981 until the *Challenger* accident in January 1986, between two and nine missions were flown yearly, with an average of four to five per year. The milestone year was 1985, when nine flights were successfully completed. The years between 1992 and 1997 were the most productive, with seven or eight yearly missions. Since 1995, in addition to its unique responsibility as the shuttle launch site, KSC also became the preferred landing site.

Over the past two decades, the SSP has launched a number of planetary and astronomy missions including the Hubble Space Telescope (HST), the Galileo probe to Jupiter, Magellan to Venus, and the Upper Atmospheric Research Satellite. In addition to astronomy and military satellites, a series of Spacelab research missions were flown, which carried dozens of international experiments in disciplines ranging from materials science to plant biology. Spacelab was a manned, reusable, microgravity laboratory flown into space in the rear of the Space Shuttle cargo bay. It was developed on a modular basis allowing assembly in a dozen arrangements depending on the specific mission requirements.⁷ The first Spacelab mission, carried aboard *Columbia* (STS-9), began on November 28, 1983. Four Spacelab missions were flown between 1983 and 1985. Following a hiatus in the aftermath of the *Challenger* disaster, the next Spacelab mission was not launched until 1990. In total, twenty-four Space Shuttle missions carried Spacelab hardware before the program was decommissioned in 1998.⁸ In addition to astronomical,

⁶ Jenkins, 268.

⁷ NASA. *NASA Shuttle Reference Manual*. (1988).

⁸ STS-90, which landed on May 3, 1998, was the final Spacelab mission. NASA. "Shuttle Payloads and Related Information." *KSC Factoids*. Revised November 18, 2002.

atmospheric, microgravity, and life sciences missions, Spacelab was also used as a supply carrier to the HST and the Soviet space station *Mir*.

In 1995, a joint U.S./Russian Shuttle-*Mir* Program was initiated as a precursor to construction of the International Space Station (ISS). *Mir* had been launched in February 1986 and remained in orbit until March 2001.⁹ The first approach and flyaround of *Mir* took place on February 3, 1995 (STS-63); the first *Mir* docking was in June 1995 (STS-71). During the three-year Shuttle-*Mir* Program (June 27, 1995 to June 2, 1998) the Space Shuttle docked with *Mir* nine times. All but the last two of these docking missions used the Orbiter *Atlantis*. Many of the activities carried out were types they would perform on the ISS.¹⁰

On December 4, 1999, *Endeavour* (STS-88) launched the first component of the ISS into orbit. As noted by Williamson, this event marked, “at long last the start of the Shuttle’s use for which it was primarily designed – transport to and from a permanently inhabited orbital space station.”¹¹ STS-96, launched on May 27, 1999, marked the first mission to dock with the ISS. Since that time, most Space Shuttle missions have supported the continued assembly of the space station. As currently planned, ISS assembly missions will continue through the life of the Space Shuttle Program.

The SSP suffered two major setbacks with the tragic losses of the *Challenger* and *Columbia* on January 28, 1986, and February 1, 2003, respectively. Following the *Challenger* accident, the SSP was suspended, and President Ronald Reagan formed a thirteen-member commission to identify the cause of the disaster. The Rogers Commission report, issued on June 6, 1986, which also included a review of the SSP, concluded “that the drive to declare the Shuttle operational had put enormous pressures on the system and stretched its resources to the limit.”¹² In addition to mechanical failure, the Commission noted a number of NASA management failures that contributed to the catastrophe. As a result, among the tangible actions taken were extensive redesign of the SRBs; an upgrade of the Space Shuttle tires, brakes, and nose wheel steering mechanisms; the addition of a drag chute to help reduce speed upon landing; the addition of a crew escape system; and the requirement for astronauts to wear pressurized flight safety suits during launch and landing operations. Other changes involved reorganization and decentralization of the SSP. NASA moved the management of the program from JSC to NASA Headquarters, with the aim of preventing communication deficiencies.¹³ Experienced astronauts were placed in key NASA management positions, all documented waivers to existing flight safety criteria were revoked and forbidden, and a policy of open reviews was implemented.¹⁴ In addition, NASA adopted a Space Shuttle flight schedule with a reduced average number of launches, and discontinued the long-term practice of launching commercial and military

⁹ Tony Reichhardt (editor). *Space Shuttle, The First 20 Years*. (Washington, D.C.: Smithsonian Institution, 2002), 85.

¹⁰ Judy A. Rumerman, with Stephen J. Garber. *Chronology of Space Shuttle Flights 1981-2000*. HHR-70. (Washington, D.C.: NASA History Division, Office of Policy and Plans, October 2000), 3.

¹¹ Williamson, 191.

¹² Columbia Accident Investigation Board (CAIB). *Report Volume I*. (August 2003), 25.

¹³ CAIB, 101.

¹⁴ Cliff Lethbridge. “History of the Space Shuttle Program.” (2001), 4.

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payloads.¹⁵ The launch of *Discovery* (STS-26) from KSC Pad 39B on September 29, 1988, marked a Return to Flight after a 32-month hiatus in manned spaceflight following the *Challenger* accident.

In the aftermath of the 2003 *Columbia* accident, a seven month investigation ensued, concluding with the findings of the Columbia Accident Investigation Board (CAIB), which determined that both technical and management conditions accounted for the loss of the orbiter and crew. According to the CAIB Report, the physical cause of the accident was a breach in the TPS on the leading edge of the left wing, caused by a piece of insulating foam, which separated from the ET after launch and struck the wing.¹⁶ NASA spent more than two years researching and implementing safety improvements for the orbiters, SRBs and ET. Following a two-year hiatus, the launch of STS-114 on July 26, 2005, marked the first Return to Flight since the loss of *Columbia*.

On January 14, 2004, President George W. Bush outlined a new space exploration initiative in a speech given at NASA Headquarters.

Today I announce a new plan to explore space and extend a human presence across our solar system . . . Our first goal is to complete the International Space Station by 2010 . . . The Shuttle's chief purpose over the next several years will be to help finish assembly of the International Space Station. In 2010, the Space Shuttle – after nearly 30 years of duty – will be retired from service...¹⁷

Following the President's speech, NASA released The Vision for Space Exploration, which outlined the Agency's approach to this new direction in space exploration.¹⁸ As part of this initiative, NASA will continue to use the Space Shuttle to complete assembly of the ISS. The Shuttle will not be upgraded to serve beyond 2010 and, after completing the ISS, the Space Shuttle program will be retired.

¹⁵ Lethbridge, 5.

¹⁶ CAIB, 9.

¹⁷ The White House. "A Renewed Spirit of Discovery – The President's Vision for Space Exploration." (January 2004).

¹⁸ NASA Headquarters. "The Vision for Space Exploration." (February 2004).

Lyndon B. Johnson Space Center

The Lyndon B. Johnson Space Center (JSC) officially opened on-site in June 1964 as the Manned Spacecraft Center (MSC).¹⁹ This approximately 1,620-acre facility is located near Clear Lake, Texas, about 25 miles from downtown Houston, in Harris County. Many of the approximate 140 buildings are specialized facilities devoted to spacecraft systems, materials research and development, and/or astronaut training. JSC also includes the Sonny Carter Training Facility, located roughly 4.5 miles to the northwest of JSC, close to Ellington Field. Opened in 1997, this facility is situated on land acquired through a lease/purchase agreement with the McDonnell Douglas Corporation. In addition, NASA JSC owns some of the facilities at Ellington Field, which are generally where the aircraft used for astronaut training are stored and maintained.

The origins of JSC can be traced to the summer of 1958 when three executives of the National Advisory Committee for Aeronautics (NACA), Dr. Hugh L. Dryden, Dr. Robert R. Gilruth, and Dr. Abe Silverstein, began to formulate a space program.²⁰ Almost immediately, Gilruth began to focus on manned spaceflight, and subsequently convened a group of his LaRC associates, who compiled the basics of what would become Project Mercury, the first U.S. manned space program. Eight days following the activation of NASA, with the approval of NASA's first administrator, Dr. T. Keith Glennan, the Space Task Group (STG) was created to implement this program. The group was formally established on November 3, 1958, with Gilruth named as Project Manager. The initial staff of the STG came from LaRC, but was soon supplemented with engineers from the Lewis Flight Propulsion Laboratory (now Glenn Research Center) and AVRO Aircraft, Ltd. of Canada.²¹

At first, the STG offices were located at LaRC. With the establishment of the Goddard Space Flight Center in Greenbelt, Maryland, in May 1959, plans were made to incorporate the STG into it, creating a new "space projects center."²² It was later decided to leave the STG at LaRC until the completion of Project Mercury; however, by January 1961, it was obvious that the STG would need to develop into an autonomous center, and on January 3, it was designated as such.²³ The May 25, 1961, announcement by President John F. Kennedy to send a man to the Moon by

¹⁹ Following the death of former President Lyndon B. Johnson, the U.S. Senate passed a resolution to rename the Manned Spacecraft Center in his memory. "MSC Is Renamed 'JSC'." *Roundup* (12, 8), March 2, 1973, 1; "Capacity Crowd View Dedication Ceremonies." *Roundup* (12, 20), August 31, 1973, 1 and 3. For ease of reference, JSC will be used throughout the text, with the exception of direct quotations from sources.

²⁰ Dryden was the Director of NACA; Gilruth was the head of the flight research section of NACA's Langley Aeronautical Laboratory (now Langley Research Center) in Hampton, Virginia; and Silverstein was the Director of NACA's Lewis Flight Propulsion Laboratory (now Glenn Research Center) in Cleveland, Ohio. As part of NASA's establishment, NACA, was deactivated and all of its personnel and facilities were transferred to NASA. James M. Grimwood. *Project Mercury: A Chronology*. (Washington, D.C.: NASA, Office of Scientific and Technical Information, 1963); Roger D. Launius. *NASA: A History of the U.S. Civil Space Program*. (Malabar, Fla.: Krieger Publishing Company, 2001), 29.

²¹ Grimwood; Loyd S. Swenson, Jr., James M. Grimwood and Charles C. Alexander. *This New Ocean: A History of Project Mercury*. (Washington, D.C.: NASA, Office of Technology Utilization, 1966), 153.

²² Swenson, et al., 115.

²³ Swenson, et al., 251.

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the end of the decade reinforced the idea that the STG needed its independence, and soon. Thus, in August 1961, John Parsons, Associate Director of the Ames Research Center (ARC), was charged with establishing a survey team to locate a site for the new center.²⁴

On September 19, 1961, James Webb, NASA Administrator, announced that Houston, Texas, would be the site for NASA's new Center for manned spaceflight.²⁵ Numerous factors influenced the choice of Houston as the home of the new Center. First of all, Rice University was willing to donate 1000 acres of land for the Center. Additionally, Houston met all of the requirements set forth in the selection criteria. For example, Ellington Air Force Base was located nearby, as were Clear Lake and Galveston Bay; these facilities could support air and barge traffic, respectively. Houston also has a year-round moderate climate, and both Rice University and the University of Houston were in close proximity to the new site.²⁶

On November 1, 1961, the STG officially became the "Manned Spacecraft Center," with Gilruth as its first Director.²⁷ The first JSC employees officially transferred to Houston from LaRC were Ed Campagna of the Facilities Division, John Powers, from Public Affairs, and Martin Byrnes, Site Manager; their first offices were two vacant dress shops in the Gulfgate Shopping Center, which were donated by its site manager, Marvin Kaplan.²⁸ The trio was assigned the responsibilities of procuring temporary office space, hiring new personnel, and meeting with local organizations to help facilitate the needs of those co-workers who would soon be joining them.²⁹ From November 1961 until April 1962, nearly 400 additional employees were transferred from LaRC to Houston; the new Center officially became operational in Houston on March 1, 1962, when Gilruth moved the JSC's headquarters there.³⁰

To supplement the 1000 acres of land promised by Rice University, NASA purchased an additional 620 acres, mainly to provide highway access for the estimated 4000 employees.³¹ In

²⁴ Swenson, et al., 363-364.

²⁵ Glennan resigned effective January 22, 1961 when President Eisenhower left office. Webb was sworn into office on February 15, 1961. Grimwood.

²⁶ From a political viewpoint, Houston was located within the district of U.S. House Representative, Albert Thomas, chairman of the House Appropriations Committee, and Texas was the home state of Vice President Lyndon B. Johnson. Dr. Robert Gilruth Oral History Interview, February 27, 1987, 273-275, *The Glennan-Webb-Seamans Project*, National Air and Space Museum.

²⁷ "STG Renamed; Will Move." *Space News Roundup* (1, 1), November 1, 1961, 1.

²⁸ Martin A. Byrnes, Jr., interview by Robert Merrifield, December 12, 1967, (Houston, TX, Archives Department, Lyndon B. Johnson Space Center), 6.

²⁹ Temporary offices were located in buildings throughout the Houston area, including the Phil Rich Building, the Farnsworth-Chambers Building, the Lane-Wells Building, the Canada Dry Bottling Building, and a Veterans Administration Building; and at Ellington Field. "Houston Site Offices Move to Rich Building." *Space News Roundup* (1, 3), November 29, 1961, 1; "Move To Houston Area Is On Schedule." *Space News Roundup* (1, 6), January 10, 1962, 1; "Photo Captions." *Space News Roundup* (1, 18), June 27, 1962, 2.

³⁰ Henry C. Dethloff. *Suddenly, Tomorrow Came...A History of the Johnson Space Center*. (Houston: Lyndon B. Johnson Space Center, 1993), 48.

³¹ "Interview with I. Edward Campagna, Assistant Chief, Technical Services Division, Maintenance and Operations." August 24, 1967, Box MERR1, Oral History Series. Johnson Space Center History Collection, University of Houston-Clear Lake; Dethloff, 48.

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September 1961, the Fort Worth Division of the U.S. Army Corps of Engineers (ACOE), under District Engineer, Colonel R. Paul West, was designated the construction agency for the new Center. Their first task was to hire an architecture/engineering (A/E) team to complete the initial design work for the new Center. Twenty teams were considered for the initial contract, and after three rounds of reviews and cuts, an A/E team headed by Brown & Root, Inc., of Houston, Texas, was selected. Partnered with them were master planners Charles Luckman Associates, Los Angeles, California; and the architectural firms of Brooks & Barr, Austin, Texas; Harvin C. Moore, Houston, Texas; MacKie & Kamrath, Houston, Texas; and Wirtz, Calhoun, Tungate, & Jackson, Houston, Texas.³² The nearly \$1.5 million contract was officially awarded in December 1961, and included general site development; master planning; design of the flight project facility, the engineering evaluation laboratory and the flight operations facility; and various site utilities.³³

Charles Luckman Associates developed the master plan of the JSC, and “did an outstanding job of meeting the functional requirements that had been set forth in developing a campus-like atmosphere for the facility.”³⁴ The central “quad” area, bounded by 2nd Street on the west, Avenue D on the south, 5th Street on the east, and Avenue C on the north, included three “lagoons” surrounded by small, man-made hills, as well as various walkways, trees, and shrubs.³⁵ Luckman Associates also advocated the use of a modular design system for the buildings with materials that could be manufactured off-site, which aided in the tight schedule for completion. Most of the buildings incorporated a poured concrete foundation, and skeletal steel walls faced with precast exposed aggregate facing (PEAF) panels. This allowed for the fabrication of the steel components while the foundation was being poured, and subsequently the manufacture of the PEAF panels while the steel skeleton was being erected.³⁶

Initial construction of the JSC was completed in three main phases. The contract for the first phase, preliminary site development, was awarded on March 29, 1962, to a joint venture of Morrison-Knudsen Construction Company of Boise, Idaho, and Paul Hardeman of Stanton, California; it amounted to \$3,673,000. They began the work in early April; it was completed on July 18, 1963.³⁷ The task included “overall site grading and drainage, utility installations including an electrical power system, a complete water supply and distribution system, sanitary and storm drainage systems, basic roads, security fence and street lighting.”³⁸

The invitations to bid for the Phase II contract of the construction, which was the first to include actual buildings, were distributed in early July 1962. At first, the task included an office

³² “Photo Captions.” *Space News Roundup* (1, 12), April 4, 1962, 2.

³³ “Design Work Contract Is Let For Clear Lake.” *Space News Roundup* (1, 5), December 27, 1961, 8.

³⁴ “Interview with James L. Ballard, Jr.” August 1, 1968, Box MERR1, Oral History Series. Johnson Space Center History Collection, University of Houston-Clear Lake.

³⁵ Campagna, August 24, 1967.

³⁶ Ballard, August 1, 1968; Campagna, August 24, 1967.

³⁷ “First Construction Contract Work Underway at Clear Lake.” *Space News Roundup* (1, 13), April 18, 1962, 1; “Clear Lake Site Commitment Now Stands At \$38,911,458.” *Space News Roundup* (3, 4), December 11, 1963, 3.

³⁸ “Interview with Jack P. Shields.” August 1, 1968, Box MERR4, Oral History Series. Johnson Space Center History Collection, University of Houston-Clear Lake; “First Construction Contract Work.”

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building, a shop building and warehouse, a garage, a central heating and cooling plant, a fire station, and a sewage disposal plant, as well as all necessary paving and utilities for these structures.³⁹ By the time bids were received and opened, the statement of work had been revised to exclude the office building, the shop building, and the warehouse, all of which were replaced by the Data Processing Center (Building 12). By the time the contract was let in October 1962, the task had changed a second time. In the end, the ACOE signed a contract with the joint venture of W.S. Bellows Construction Corporation and Peter Kiewit & Sons Corporation, both of Houston, in the amount of \$4,145,044, for the construction of Building 12, the sewage disposal plant, the central heating and cooling plant, the fire station, and a water treatment plant and associated building.⁴⁰ Of these facilities, the fire station was the first to be completed in September 1963; the central heating and cooling plant was last, finished in December 1963.⁴¹

Phase III of JSC's construction incorporated the largest grouping of buildings under one contract. The invitations to bid on this phase were issued on September 25, 1962, and listed ten buildings with an approximate total area of 760,000 square feet.⁴² Similar to Phase II, the statement of work was revised prior to the submittal of the bids to include eleven office and lab buildings, and the temperature and humidity control machinery for the entire site. Interested firms were also asked to submit alternate proposals that incorporated additional facilities, which NASA was hoping to add to the contract if funding became available.⁴³ On December 3, 1962, Colonel Francis P. Koish, the new ACOE District Engineer, signed the official contract, which amounted to roughly \$19 million, with the joint venture of C.H. Leavell and Company of El Paso, Texas, Morrison-Knudsen Construction Company, and Paul Hardeman. Eleven major facilities were part of this contract, including the project management building, the cafeteria, the flight operations and astronaut training facility, the crew systems laboratory, the technical services office and shop buildings, the systems evaluation laboratory, a spacecraft research lab and office building, and a data acquisition building. Funding for the additional facilities had become available by this time, so additional support buildings, such as the shop building and warehouse, were also included. Per the contract, the buildings were to be ready for occupancy in 450 calendar days.⁴⁴

In October 1963, the Logistics Division became the first to move into its complete facility, the Support Office (Building 419) and its shops and warehouse (Building 420). By the end of 1963,

³⁹ "Second Major Clear Lake Building Contract Awarded." *Space News Roundup* (1, 17), June 13, 1962, 8.

⁴⁰ "Bids Open On Phase Two Of Clear Lake Work." *Space News Roundup* (1, 23), September 5, 1962, 1; "Phase II Contract Goes to Bellows, Peter Kiewit, Sons." *Space News Roundup* (1, 25), October 3, 1962, 8; Shields, August 1, 1968.

⁴¹ "Photo Captions." *Space News Roundup* (2, 23), September 4, 1963, 3; "Central Heating and Cooling Plant Completed." *Space News Roundup* (3, 5), December 25, 1963, 8.

⁴² "First Building Contract To Be Let In November." *Space News Roundup* (1, 20), July 25, 1962, 8.

⁴³ "Bids Open On Phase 3 Of Center Construction." *Space News Roundup* (2, 2), November 11, 1962, 1-2.

⁴⁴ "19 Million Dollar Construction Contract Signed." *Space News Roundup* (2, 4), December 12, 1962, 1; "MSC 'Site' Three-Fourths Complete, First Move Scheduled Next Month." *Space News Roundup* (2, 24), September 18, 1963, 1; Shields, August 1, 1968.

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twelve additional buildings were certified as operational.⁴⁵ The major relocation to the new Center occurred between February and April 1964, and included the occupation of facilities such as the Auditorium and Public Affairs Building (Building 1), the Flight Crew Operations Office (Building 4), the Flight Crew Operations Lab (Building 7), the Systems Evaluation Lab (Building 13), and the Spacecraft Technical Lab (Building 16). The Director's office officially moved on March 6, 1964. During May, the Instrument and Electronics Lab (Building 15) was occupied, followed by the Manned Spaceflight Control Center, Houston (Building 30) at the end of June, when all leases on the temporary facilities expired.⁴⁶

Since its beginnings as the STG, JSC has had four main tasks with regard to manned spaceflight: spacecraft development; mission control; research and development; and astronaut selection and training.⁴⁷ The basic design guidelines for each space vehicle used during the Mercury, Gemini, Apollo, and Space Shuttle programs were developed by JSC engineers. JSC subsequently managed the contracts with private firms for spacecraft manufacture. It was also the responsibility of JSC engineers to develop the proper interfacing between the spacecraft and its respective launch vehicle, which was developed separately by NASA's MSFC (Mercury-Redstone, Apollo-Saturn, Shuttle SRBs, ET, and SSMEs) or the U.S. Air Force (Mercury-Atlas, Gemini-Titan).⁴⁸

In addition to spacecraft development and astronaut training, JSC is also responsible for mission control. Mission control begins once the space vehicle has cleared the launch pad, and ends when the vehicle lands.⁴⁹ The key figure of mission control is the Flight Director, who makes all final decisions with regards to the proceedings. All communication between the ground and the spacecraft is coordinated through the Spacecraft Communicator. The mission control team also includes personnel who monitor all aspects of the space vehicle, such as flight dynamics, communications links, data processing, and instrumentation. Between missions, the controllers plan for the next flight, conduct various in-house training exercises, and aid with astronaut training.⁵⁰

In conjunction with vehicle design, JSC has historically conducted related research and development, which generally falls into four categories: materials, electrical systems, life

⁴⁵ "MSC 'Site' Three-Fourths Complete;" "Major Move To Clear Lake Begins February 20." *Space News Roundup* (3, 6), January 8, 1964, 1.

⁴⁶ "Majority of MSC Personnel Relocated At New Site." *Space News Roundup* (3, 11), March 18, 1964, 2; "Final Relocation Of Center Employees Begins Today." *Space News Roundup* (3, 18), June 24, 1964, 1.

⁴⁷ "Gilruth Cites MSC Progress Despite Difficult Relocation." *Space News Roundup* (1, 19), July 11, 1962, 1.

⁴⁸ Archaeological Consultants, Inc. (ACI). *Survey and Evaluation of NASA-owned Historic Facilities and Properties in the Context of the U.S. Space Shuttle Program. Lyndon B. Johnson Space Center, Houston, Texas.* November 2007, Section 4.3.1.

⁴⁹ Likewise, those who designed the launch vehicle generally handled the actual launch process. It should be noted that the Kennedy Space Center, which has conducted all launches for Apollo and Space Shuttle, grew from MSFC's Launch Operations Directorate, which controlled the initial Mercury-Redstone launches.

⁵⁰ All Mercury missions and the first four Gemini missions were controlled from the old Mercury Control Center at Cape Canaveral, Florida. The Mission Control Center at Houston took over starting with Gemini IV. ACI, Section 4.3.3.

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systems, and life sciences. The materials category includes development and testing of active thermal control systems as well as spacecraft structure testing. Electrical systems includes testing of the various interfaces with spacecraft hardware and software, ensuring there are no anomalies within the wiring and electronics systems, and confirming the ability of the spacecraft's communications systems to connect to relay satellites and ground stations. Life systems and life sciences are inherently connected to one another and include the astronauts' spacesuits and backpacks, as well as ensuring that their meals meet nutritional guidelines, taste good and store well.⁵¹

The last major task of JSC, and probably the most well-known besides mission control, is astronaut selection and training. From the original "Mercury 7," JSC has determined the criteria for astronaut selection and handled all interviews and examinations during the selection procedure. Additionally, the Center has established all training curricula, which provide astronauts with the basic knowledge needed to fly a mission and survive in emergency circumstances, as well as more specific training for tasks associated with a particular mission. Since Project Gemini, program-specific spacecraft simulators and trainers have been located within various buildings at JSC for astronaut training.⁵²

⁵¹ ACI, Section 4.3.4.

⁵² ACI, Section 4.3.2.

Crew Systems Laboratory (Building 7)

Construction

The Crew Systems Laboratory (CSL) was constructed between December 1962, and March 1964, by the joint venture team of C.H. Leavell and Company of El Paso, the Morrison-Knudsen Company, Inc. of Boise, Idaho, and Paul Hardeman, Inc. of Stanton, California for a cost of approximately \$1.549 million. Building 7 is one of the eleven original buildings constructed at the JSC. A 55,000 square foot addition (Building 7A) was made to the original 109,026 square foot building in 1966, at a cost of \$1.494 million. In 1970, the addition of Building 7B increased the overall size of the facility by 2926 square feet. Smaller additions to Building 7 were made in 1967 (1272 square foot) and 1969 (546 square foot). The most recent major modification, in 1995, was the 3886-square foot addition to the Equipment Receiving Area.

The Wing E High Bay (Room 1000) of Building 7, known as the Environmental Test Area, contains the historically significant facilities which support the Space Shuttle program, including the 8', 11', and 18' vacuum chambers and their ancillaries. Only the 18' chamber was built specifically for the SSP. The 2', 10'⁵³ and 20'⁵⁴ chambers, also located within Room 1000, lack noteworthy historical associations with the Space Shuttle program. Collectively, the 8' and the 20' chambers, originally used for Project Gemini, are the oldest.

The human-rated **8' Vacuum Chamber**, also known as the System/Component Vacuum Test Facility, arrived in Houston in May 1962, from Air Force surplus. It was modified three months later by the addition of an 8'-diameter loading door (Photo 22) and explosion-proof interior lights. Following a complete overhaul and upgrading in Hangar 135 at Ellington Field during February 1964, the chamber was installed in Building 7 in July 1964. Portable Life Support System (PLSS) checkout consoles were installed in the adjacent control room in October 1965. The 8' chamber was active during Project Gemini and the Apollo Program, and was upgraded in 1973, to support the Apollo-Soyuz Test Project (ASTP). Two years later, in November 1975, the equipment that supported the ASTP was removed.⁵⁵ Subsequently, the 8' chamber was used to

⁵³ The 10' chamber was used briefly in the late 1970s, at ambient pressure, for development testing of the Shuttle environmental control system. Originally located at Langley Research Center, it was relocated to Building 7 in May 1973. In February 1975, it was moved to south of the 20' chamber, and the chamber controls were built up on its south side. Casey, L.O. "Crew Systems Laboratories of the Engineering and Development Directorate Johnson Spacecraft Center – NASA." Report Number STB-F-218, 1977, 24, 28.

⁵⁴ Construction of the 20' chamber, directly to the south of the 8' chamber, started in February 1964. Beginning in 1965, it was used in support of Project Gemini and the Apollo Program. In 1971, the 20' chamber was configured into a reduced habitability test bed for the Skylab Medical Experiment Altitude Test (SMEAT). Using a crew of three, this test simulated a 56-day Skylab mission. The 20' chamber also was used for the Lunar Mars Support Test Project in 1997-1998. This 91-day test of the regenerative life support system was accomplished with a crew of four test subjects (non-astronaut). NASA JSC. "Human-related Altitude Chamber Complex."

⁵⁵ Casey, 14.

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support the design verification and flight qualification testing of the Shuttle Extravehicular Mobility Unit (EMU) PLSS backpack.⁵⁶

The **11' Vacuum Chamber** was first used in November 1966, for off-site manned tests. It was moved to JSC in May 1968, and used during the Apollo Program for evaluative tests of the Lunar Module environmental control PLSS, pressure suits, and EVA components.⁵⁷ Two treadmills, used for metabolic determination, were installed in 1970 and 1971. Modifications to support the Space Shuttle program included removal of the Lunar Module cabin wall heater/cooler in 1977. In 1978, funding was approved for expanding the existing 11' chamber vacuum system to incorporate the Shuttle Flash Evaporator System in the Shuttle Environmental Control and Life Support System (ECLSS) boilerplate (including airlock hardware). To enable extended systems evaluation and crew training tests, modifications included installing a vacuum line from the 11' chamber to a new vacuum cylinder boilerplate (18' vacuum chamber) sized to simulate the flight airlock; constructing a platform with stairway and an enclosure to surround the airlock boilerplate; extending the existing fire suppression and alarm system to the new airlock and entry room type enclosure; and installing repressurization valves, altitude limiting valves, and cable trays. Plumbing, electrical utilities, and high pressure GO₂ and GN₂ systems also were installed to allow reduced chamber pressure.

The **18' Vacuum Chamber**, known as the Shuttle EMU/Airlock/Life Support Test Facility, or the ETA (Environmental Test Article), is the only chamber in Room 1000 that was built specifically for the SSP. While no longer used, it originally housed the Shuttle ECLSS and the Airlock Test Article (ATA). The aluminum shell of the ETA, a large metal cylinder, was built ca. 1979, by Rockwell in Downey, California; the interior ETA mid-deck was built by the Chicago Bridge and Iron Company. NASA engineers at JSC built up the interior with structural ribs and foam to match the inside cabin of the orbiter.⁵⁸ Outfitted as the orbiter crew compartment, this test article was configured to match the volume of the real Shuttle cabin, and to simulate the environment of the orbiter's flight and mid-decks. It contained all the systems for the Shuttle cabin, including waste management, life support, and thermal, as well as bunk beds to accommodate seven test subjects for pre-Shuttle and post-Shuttle environmental control systems tests. The ATA, located on the east side of the mid-deck, was manufactured off-site by

⁵⁶ The EMU hardware and accessories, including the PLSS, helmet, communications cap, and locking rings for the helmet and gloves, are manufactured by the Hamilton Sundstrand Division of United Technologies in Windsor Locks, Connecticut. ILC (International Latex Corporation) Dover of Frederica, Delaware makes the soft components, including the arm assemblies, gloves, and the Lower Torso Assembly (LTA). Both Hamilton Sundstrand and ILC Dover originally received contracts to build the EMU in 1974. This was followed by a period of spacesuit research and development between 1975 and 1980. The first EMU units were delivered in 1982, and first flown on STS-4 in July 1982. In 1984, STS-6 marked the first use of the new EMU during an EVA by astronauts Story Musgrave and Don Peterson. The first EVA had been planned for STS-5, but neither suit operated properly. With the building of the International Space Station, Hamilton Sundstrand and ILC Dover refined the Shuttle EMU by making the suit modular. This allowed it to be left on the ISS for up to two years. ILC Dover, Inc. "Space Suit Evolution From Custom Tailored to Off-the-Rack." 1994.

⁵⁷ Casey, 29

⁵⁸ Henry "Hank" Rotter, interview by Jennifer Ross-Nazzal, April 20, 2009, Houston, Texas. Transcript on file, Tessada & Associates, Houston, Texas, 3.

Rockwell, shipped to JSC, attached to the ETA, and connected to the vacuum systems through the 11' chamber.⁵⁹

Space Shuttle Program Spacesuit and Environmental Control Systems Testing

Building 7 is managed by the Crew and Thermal Systems Division of the JSC Engineering Directorate. Originally named the Life Systems Laboratory, it contained five major test facilities: two advanced environmental control laboratories and three human-rated vacuum chambers (8', 11', and the 20'). These facilities supported flight crew familiarization and the testing and evaluation of hardware used in the early manned spaceflight programs, including Gemini, Apollo, and the ASTP.

Beginning in the mid-1970s, facility upgrades and equipment modifications were initiated in support of the new Space Shuttle program. Since the late 1970s, the Environmental Test Area of the Crew Systems Laboratory has supported the Space Shuttle program in three areas: spacesuit (EMU) testing; environmental control systems testing; and astronaut training. The 8', 11', and 18' vacuum chambers located in the Wing E High Bay of Building 7 have been used for the design verification and performance testing of Shuttle spacesuits, including the Manned Maneuvering Unit (MMU) and the EMU. The 8' Vacuum Chamber is used exclusively to test the EMU backpack, unique to the Space Shuttle program. Certification and recertification tests conducted in the 8' chamber have resulted in progressive upgrades to the EMU backpack. The 11' Vacuum Chamber, which supports the next step in the spacesuit certification process, tests the complete suit and backpack system. Simulations and verification testing conducted in the 18' Vacuum Chamber have resulted in important modifications and advancements in the Shuttle environmental control system. Taken together, these tests have provided valuable data on the long-term performance of Shuttle spacesuits, including the life support systems critical to the health and safety of humans living and working in space.

The Shuttle suit and backpack were developed and tested independently.⁶⁰ In general, as the suit design changed over time, new tests were performed to verify the design. In 1977, ILC Dover, developer of the Shuttle spacesuit and subcontractor to Hamilton Sunstrand, builder of the life support system backpack, began testing prototype spacesuits, including launch-entry suits, in Building 7.⁶¹ After the first group of thirty-five Shuttle astronauts was selected in 1978, all were measured for their size. The prototype suits initially were subjected to endurance testing at the manufacturing site in Delaware. They were then sent to JSC, where the astronauts evaluated their comfort, mobility, and usefulness; this evaluation was done in the Building 7 suit laboratory, outside of the Wing E High Bay. Depending upon the size of the spacesuit, astronauts were selected to evaluate their design and performance. Prior to STS-1 in 1981, astronauts John

⁵⁹ Walter W. Guy, interview by Rebecca Wright, January 29, 2007, Houston, Texas. Transcript on file, Tessada & Associates, Houston, Texas, 7.

⁶⁰ Ronald L. Newman, interview by Jennifer Ross-Nazzal, October 21, 2009, Houston, Texas. Transcript on file, Tessada & Associates, Houston, Texas, 20.

⁶¹ Newman, interview, 2.

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Young and Bob Crippen went through chamber tests in their own suits to make sure they fit right.⁶²

Beginning in September 1979, a three-month long evaluation of a high fidelity mockup of the MMU⁶³, manufactured by the Martin Marietta Corporation, was initiated in Building 7. The purpose of this evaluation was to check out the backpack with different sized astronauts. Tests included fit checks and the mechanical operation of the unit's extendible arms which telescoped for individual fit. Tests also were run to determine astronaut visibility and reach while using the unit.⁶⁴

During the Apollo era, humans were used to test spacesuits in the 8' Vacuum Chamber. A treadmill (no longer extant) was used to speed up the metabolic rate of the tester.⁶⁵ A manual system using cables and pulleys was employed to service the spacesuit. Since the beginning of the Space Shuttle program, the suits are attached to equipment that simulates the metabolic processes of a working human being, and all operations are from the outside of the 8' chamber. Water systems and recharge for the suit are provided by the Services and Cooling Umbilical (SCU). A metal "fork" (Photo 27) holds the backpack, and a mechanized "arm" and remote actuators support the testing activities.

Although human-rated, the 8' Vacuum Chamber complex currently is dedicated primarily to "Canned Man" verification testing of the EMU life support systems using a human metabolic simulator.⁶⁶ It provides controlled metabolic loading, and can simulate heat loads, carbon dioxide generation, oxygen consumption, and water generation. While functionally obsolete, the chamber airlock is still intact. Approximately two recertification tests of the Hard Upper Torso (HUT) are conducted each year in the 8' chamber.⁶⁷ From here, the HUT goes to the 11' chamber for the next stop required for certification testing.

During the summer of 1992, for example, two sets of qualification tests of the PLSS-4 were conducted. Testing entailed 100 runs in the 8' chamber requiring a total of 800 hours and the involvement of twenty-five people.⁶⁸ Such tests provided valuable engineering data on the long-term performance of the Shuttle EMU PLSS backpack, especially components that are considered consumable (e.g., water filter sublimator plates). The next step was to perform tests on the space suit itself. In 1993, twenty-five manned simulated space station runs were performed – about one EVA a week for 180 days in the 11' chamber using a different PLSS.⁶⁹

⁶² Newman, interview, 19.

⁶³ The MMU was an untethered backpack propulsion unit that allowed astronauts to maneuver in space independent of the Orbiter. It was used on three missions in 1984, and then retired from use after the *Challenger* accident.

⁶⁴ "New unit allows mobility outside orbiter." *Roundup*. (18, 18), September 7, 1979, 1 and 4.

⁶⁵ Mary P. Cerimele. Personal communication with Joan Deming and Trish Slovinac, JSC Crew Systems Laboratory, November 4, 2009.

⁶⁶ "Human-related Altitude Chamber Complex."

⁶⁷ Cerimele; Only the HUTs are tested, because it is the only part of the Shuttle spacesuit that has a working system.

⁶⁸ Kelly Humphries, "Doubly Durable." *Space News Roundup*. (31, 30), July 31, 1992, 3.

⁶⁹ Humphries, 3.

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The 11' Vacuum Chamber is currently used for EMU testing with an actual (human) metabolic load. During the “early days,” astronauts performed an overnight “prebreathe” in the outer airlock prior to testing in the inner chamber.⁷⁰ Historically, two beds accommodated both the astronaut and the technician whose job it was to suit up the astronaut (Photo 46); one was removed when the 2' Vacuum Chamber was installed. The outer airlock also contains a small “hard vacuum” (above 120,000 feet of altitude) chamber, installed ca. 2003, that is used to test the spacesuit gloves plus materials that will be manipulated with gloved hands. The 11' chamber also has supported altitude certification testing of the Atmospheric Revitalization Pressure Control System (ARPCS).⁷¹

Every spacesuit goes through a test in the 11' chamber to make sure that all the systems work properly. Suited astronauts exercise on the treadmill to test the thermal control system. Each test involved the work of a team of approximately twenty to twenty-five individuals.⁷² Among these were the emergency technicians. During the test, one or two technicians (on an oxygen mask) were positioned in the partially depressurized anterior chamber. In the event of an emergency, the technician was the first person able to go inside the test chamber to repressurize it. Since the technician was “partially there,” “the chamber didn’t have to come up to full atmospheric pressure for him to be able to go in and render help to the crew member if there was an emergency.”⁷³ Other members of the test team included the suit technicians whose responsibilities included suiting up the crew member. During the test, the suit technician was positioned outside the chamber, and in the case of an emergency, he/she would get the astronaut out of the suit quickly, if needed. About eight test conductors worked inside the control room, and other personnel operated the vacuum pumps. Other participants, including a doctor and a suit engineer, monitored the test process from “back rooms.”⁷⁴

In addition to spacesuit design verification, qualification, and certification testing, the Crew Systems Laboratory supports tests of new environmental control systems for long duration missions, thereby meeting NASA’s requirements to maintain a habitable environment for the Shuttle orbiter. For example, in March-April of 1992, the 11' chamber was used to test a new air scrubber, the Regenerable Carbon Dioxide Removal System for Extended Duration Orbiters, prior to its first use on STS-50 in June 1992. This test was designed to determine whether the new system could handle the metabolic output of seven humans living and working in a closed environment about the size of the shuttle cabin for sixteen days. Successive groups of seven female and seven male subjects were used. The test was done under normal Shuttle pressure of 14.7 pounds per square inch (psi). Later tests were conducted to evaluate performance at 10.2 psi, the pressure at which Shuttle crews prebreathe before spacewalks.⁷⁵

⁷⁰ Cerimele.

⁷¹ Casey, 29.

⁷² Newman, interview, 9-10.

⁷³ Newman, interview, 9.

⁷⁴ Newman, interview 10.

⁷⁵ “Air scrubber gets human test.” *Space News Roundup*. (31, 15), April 10, 1992, 4.

Astronaut Training

The Crew Systems Laboratory also provides high fidelity simulated environments in which Shuttle crew train for EVAs. One of the most important aspects of astronaut training involves the use of the EMU, including suiting up procedures. Each astronaut scheduled to conduct an EVA goes through an EMU familiarization test run in the 11' chamber.⁷⁶ As part of this test, the astronaut exercises on the treadmill to increase his or her metabolic rate, allowing for evaluation of the suit's cooling system. Formerly, each astronaut also completed a "crew training run" in the man-rated, high-fidelity ATA, which contained all the airlock controls and umbilical connections. They put their spacesuits on, the pressure inside the airlock mockup was dropped, and the astronauts were trained in the kinds of procedures that they would do in space.⁷⁷ Every test run provided an opportunity for problem solving. During "malfunctioning training," the astronaut imagined a specific problem (e.g., a suit leak, with resulting loss of pressure). Using an emergency response checklist attached to the arm of the spacesuit, the astronaut followed steps to isolate and solve the problems.⁷⁸ In addition to learning procedures, the training runs allowed each astronaut to feel what it was like to function in the spacesuit.

Since Shuttle EVAs are no longer performed out of the Orbiter's airlock, the Shuttle ATA is considered functionally obsolete, and is no longer used.⁷⁹ It has been stripped of its equipment in preparation for modifications to provide testing of equivalent systems in support of future programs.

⁷⁶ Frank H. Samonski, interviewed by Jennifer Ross-Nazzal, December 30, 2002, Houston, Texas. Transcript on file, Tessada & Associates, Houston, 53.

⁷⁷ Newman, interview, 6.

⁷⁸ Newman, interview, 11.

⁷⁹ Astronauts now train for EVAs in the Space Station Airlock Test Article (SSATA).

Physical Description

The Crew Systems Laboratory has approximate overall dimensions of 275' in length (north-south), 247' in width (east-west), and 45' in height. The entirety sits on a concrete foundation and has a flat, built-up roof. The facility is divided into two main wings (Wing E and Wing W), a connector, and a small addition on the east elevation of Wing E.

Wing W (Photos 1-3 and 9) roughly measures 196' in length (north-south), 95' in width (east-west), and stands 45' in height. Its walls are constructed of plate glass window. The first floor walls are shaded by a 9'-deep pre-cast exposed aggregate facing (PEAF) panel canopy that is supported by free-standing pillars, which sit roughly 4' from the glass wall and are spaced at 27'-6" on center. The upper two floors are shaded by a 5'-deep PEAF panel canopy. There is only one exterior entrance to this wing, a pair of glass swing doors near the north end of the east elevation. The interior of Wing W is comprised of two service cores, one to the north and one to the south, with mechanical equipment areas and offices between the cores, and offices around the perimeter.

The central connector has rough dimensions of 64' in length (north-south), 20' in width (east-west), and 15' in height. Its north and south walls are composed of a steel skeleton faced with PEAF panels. The east wall abuts the exterior wall of Wing E; the west wall flows directly into the first floor of Wing W. On the roof of the connector is an 8'-wide, 15'-high enclosed walkway that extends between the second floors of Wing W and Wing E.

Wing E (Photos 4-8) measures approximately 246' in length (north-south), 106' in width (east-west), and 45' in height. Its walls are composed of a steel skeleton faced with PEAF panels. This wing features one pair of metal swing doors, two single metal swing doors, and one metal rolling door on the north elevation; one metal swing door on the east elevation; and one pair of metal swing doors on the south elevation. Internally, Wing E can be divided lengthwise into a central High Bay flanked by three levels of support areas along the east and west walls. As defined by the "Survey and Evaluation of NASA-owned Historic Facilities and Properties in the Context of the U.S. Space Shuttle Program, Lyndon B. Johnson Space Center, Houston, Texas," the CSL receives its significance from this High Bay (Room No. 1000), which contains four vacuum chambers (8', 11', 18', and 20').⁸⁰ Only the 8', 11', and 18' chambers supported the Space Shuttle program.

To the east of Wing E is a one-level support area with approximate dimensions of 241' in length (north-south) and 67' in width (east-west); its height varies. Constructed of a steel skeleton faced with PEAF panels, this area contains the various transformers and mechanical equipment necessary to operate the vacuum chambers within the High Bay.

The Wing E High Bay (Photos 10 and 11) measures approximately 246' in length (north-south) and 45' in width (east-west). It has one pair of metal swing doors to the exterior on the south

⁸⁰ ACI, 6-6.

wall, and one metal swing door and one metal rolling door to the exterior on the north wall. On the east and west walls are numerous doorways that lead to various High Bay support areas, such as control rooms and equipment rooms. The inner wall surfaces of the High Bay are faced with plaster applied to metal lath, and it contains an exposed metal deck ceiling. Across the floor is a series of trenches used to run cabling and utilities to the four vacuum chambers. Additionally, there is a 20-ton overhead bridge crane, which rolls north-south along tracks positioned roughly 30' above the finished floor on the east and west walls. The four vacuum chambers are situated just east of the High Bay's center-line; the 8' Vacuum Chamber sits at the north end with the 20' Vacuum Chamber to its south, while the 18' Vacuum Chamber sits at the south end with the 11' Vacuum Chamber to its north.

8' Vacuum Chamber

The 8' Vacuum Chamber complex (Photos 12-15) has approximate overall dimensions of 32' in length (north-south), 20' in width (east-west), and 20' in height, which includes the test chamber, airlock, anteroom, and control room. The spaces are arranged so that the anteroom, airlock, and chamber extend from north to south, in that order, with the control room above on a platform. Personnel access to the chamber is typically through the anteroom.

The anteroom (Photo 16), which currently serves as a preparation and storage area, has rough dimensions of 11' in length and width, and 8' in height. Its east, north, and west walls are composed of metal studs faced with gypsum board; the room's south wall is the north end of the airlock with a stud wall built around it. The ceiling of the anteroom is clad with gypsum board, and the floor is faced with vinyl tile. The room is entered through a metal swing door within the north wall, which is reached via a small platform and steps. Along the east and west walls are metal shelves and cabinets. From the anteroom, the chamber's airlock is accessed through a 4'-9"-high x 2'4"-wide door (Photo 17) with a circular viewing port; to either side of the door is a rectangular viewing port. The airlock has an overall diameter (height) of 8' and a length of 3'. Features of the airlock (Photos 18-20) include a rectangular viewing port on the east side and a utility connection port on the west side. The south end contains a 4'-9"-high x 2'4"-wide door, with a circular viewing port, that provides personnel access to the test chamber.

Like the airlock, the test chamber (Photos 21-25) has an 8' diameter, but has a length of 14' (north-south). The internal surfaces of the chamber are characterized by metal grating (floor), small square viewing ports and utility connections (east and west sides), and a support track on the ceiling. The entire south end is an 8'-diameter door, which opens out, allowing end loading of larger test articles or equipment. In the upper half of the door is a rectangular viewing port; in the lower half is a utility connection port. The principle feature of the test chamber is the large metal support frame near the south end of the chamber (Photos 26-30). This frame, used to support the EMU, consists of a center post that supports two arms, one which extends to the east, the other to the west. At the end of each arm is a rectangular connection plate. Surrounding this frame is a light steel skeleton that holds the various umbilical connections, which generate the

“Canned Man” metabolic load for the testing sequences.⁸¹ Surrounding the outside of the vacuum chamber are its various mechanical and electrical equipment panels, as well as operator consoles that control metabolic loads, gas inlet and outlet, water inlet and outlet, and temperature.

Situated above the 8' Vacuum Chamber is its associated control room (Photos 36 and 37), which is mounted atop a steel platform. Constructed of metal stud walls faced with gypsum board, it has approximate overall dimensions of 18' in length (east-west) and 16' in width (north-south), with a floor-to-ceiling height of 9'. A set of “L”-shaped steps rises to a 16'-long, 6'-wide platform that provides access to the control room by a metal swing door at each end of the room's east wall. Between the two doors is a pair of one-light, fixed windows; a second pair of such windows is situated on the north wall. The remaining walls are void of openings. Along the east wall of the control room is an 8'-long, 7'-deep, 1'-high, platform that contains a row of control consoles along the west end. A second row of control consoles, which rests on the main floor, is located to the west of the platform. Four video monitors are suspended from the ceiling of the control room.

11' Vacuum Chamber

The 11' Vacuum Chamber complex (Photos 40-43) is situated on a concrete platform towards the south end of the High Bay, and, including this platform, has approximate overall dimensions of 41' in length (north-south), 27' in width (east-west), and 20' in height. Its components are aligned north to south, with the anteroom at the north end, followed by the dual test chamber (comprised of an outer airlock [north] and an inner airlock [south]), and, finally, a vacuum plenum space; the control room is completely separate. Surrounding the outside of the chamber complex are its various mechanical and electrical equipment panels, as well as operator consoles that control air inlet and outlet, gas inlet and outlet, water inlet and outlet, and temperature.

Similar to the 8' Vacuum Chamber, personnel access to the chamber is through the anteroom (Photo 44), which has rough dimensions of 10' in length (north-south), 8' in width (east-west), and 8' in height. The east, north, and west walls are composed of metal studs clad with gypsum board, while the south wall is formed from the north end of the vacuum chamber. The ceiling is also faced with gypsum board, while the floor is clad with vinyl tile. A pair of metal swing doors on the west wall, reached via a concrete ramp, provides personnel access to the chamber. A small, rectangular window characterizes the east wall. From the anteroom, the chamber's outer airlock is accessed through a 6'-high x 2'6"-wide door.

The outer airlock (Photos 45-47) has an overall diameter (height) of 11' and a length of 10'. The working floor surface is comprised of metal panels, and the ceiling contains an air vent and a few utility pipes. Its north end contains two circular viewing ports, one on each side of the door; the east side has one small utility connection port. Along the east side is a six-compartment metal storage cabinet, the top of which is fitted with a cushion to provide seating. The most prominent

⁸¹ See page 16.

feature of the outer airlock is the 2' Vacuum Chamber at the center of the west side (Photos 48-51). It is comprised of a large, stainless-steel ovoidal compartment supported by steel posts, with the vacuum plenum outside of the airlock, to its west. The east face of the compartment has a large door, with a viewing port in the top half and two openings in the lower half, where an astronaut or technician inserts their gloved hands to perform an operation.

The inner airlock (Photos 54-58) is accessed through a 6'-high x 2'6"-wide door (Photo 52) at the south end of the outer airlock; a circular viewing port is located on each side of the door. The east wall of the inner airlock is characterized by a circular viewing port, a cable tray to its north, and a utility connection port. The west wall features a rectangular viewing port, a utility connection port, and two wall-mounted control panels. The floor of the inner airlock contains a treadmill that can be oriented either north-south or east-west, around which is a support frame for the test subject to hold. Attached to the ceiling of the airlock is a "weight reducer," which helps to support the EMU that the crewman may be wearing.⁸²

In a separate room (Room No. 1024) to the east of the 11' Vacuum Chamber is its associated control room (Photos 61 and 62). Constructed of metal stud walls faced with gypsum board, it has approximate overall dimensions of 24' in length (east-west) and 23' in width (north-south), and a floor-to-ceiling height of 10'. It has a raised tile floor, and an acoustical tile drop ceiling. The room is accessed by a pair of one-light, metal swing doors within its west wall; a secondary metal swing door in the east wall leads to the back room. Additionally, both the east and west walls contain a pair of one-light, fixed windows; the north and south walls are void of openings. There are three rows of control consoles, which face west, and a fourth row that is situated along the north wall. Five video monitors are suspended from the ceiling along the west wall of the control room.⁸³

18' Vacuum Chamber

The 18' Vacuum Chamber complex (Photos 66-69) has approximate overall dimensions of 29' in length (east-west), 27' in width (north-south), and 25' in height, which includes the test chamber (comprised of the ETA Cabin and Airlock), the Clean Room, and two sets of access stairs. These spaces are arranged so that the ETA Cabin sits to the west, with the airlock attached to its east side, the Clean Room on a platform above the airlock, and the access stairs to the south (an inner set directly adjacent to the ETA Cabin, and an outer set to its south).

The ETA Cabin is a horizontal cylinder with an 18' diameter and a length of 18'-6" (east-west). It is entered through a 4'-high x 2'-6"-wide hatch towards the east end of the south side, which is reached by the inner set of access stairs. Internally, the cabin is divided into two levels to mimic the orbiter's crew compartment in volume only.⁸⁴ The lower level (Photos 70-72), with curved

⁸² See page 18.

⁸³ This also serves as the control room for the 18' Vacuum Chamber complex.

⁸⁴ The testing done within the chamber is strictly environmental, therefore there is no necessity for the various control consoles and seats found within space shuttle mock-ups or simulators, which are strictly used for astronaut training.

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walls, metal floor and ceiling panels, and various build-outs, has the volumetric equivalent of the orbiter's mid-deck. The walls are fitted with metal ribs to provide structural bracing, and a steel column towards the east end helps support the upper level. A 3'-diameter hatch (an exact replica of that found on the orbiter's mid-deck) is located within the east wall (Photo 73); a ladder in the northeast corner provides access to the upper level. Similar to the lower level, the upper level (Photos 76 and 77) contains metal floor and ceiling panels, and has various build-outs to give it the same volume as the orbiter's flight deck.

The 3'-diameter hatch provides access to the ETA Airlock (Photos 74 and 75) from the Cabin, exactly as if the test crew were within one of the orbiters. Like the actual airlock of an orbiter, it is a vertical cylinder, with an approximate diameter of 6' and height of 6'-6". In addition to the hatch that opens into the EVA Cabin, there is a mount for a replica aft hatch on the east side, and a 5'-4"-diameter ceiling hatch that opens into the above Clean Room. At the time of documentation, all of the internal panels, replicas of those found in an actual orbiter airlock, had been removed in preparation for modifications to the chamber.⁸⁵

Above the ETA Airlock is its associated Clean Room (Photos 78 and 79), which has approximate overall dimensions of 23' in length (north-south), 11' in width, and 14' in height. It is reached via the outer set of access stairs, through a pair of metal swing doors that open onto the stair landing. The walls and ceiling of the Clean Room are constructed of metal studs faced with gypsum board; the floor is clad with vinyl tile. A 2-ton bridge crane is mounted to the ceiling, in line with the Airlock hatch. The crane's hook is moveable within the bridge support, along an east-west axis. Other features of the Clean Room include video monitors and a storage cabinet on the north wall, and various equipment hook-up panels on the other walls.

⁸⁵ Cerimele.

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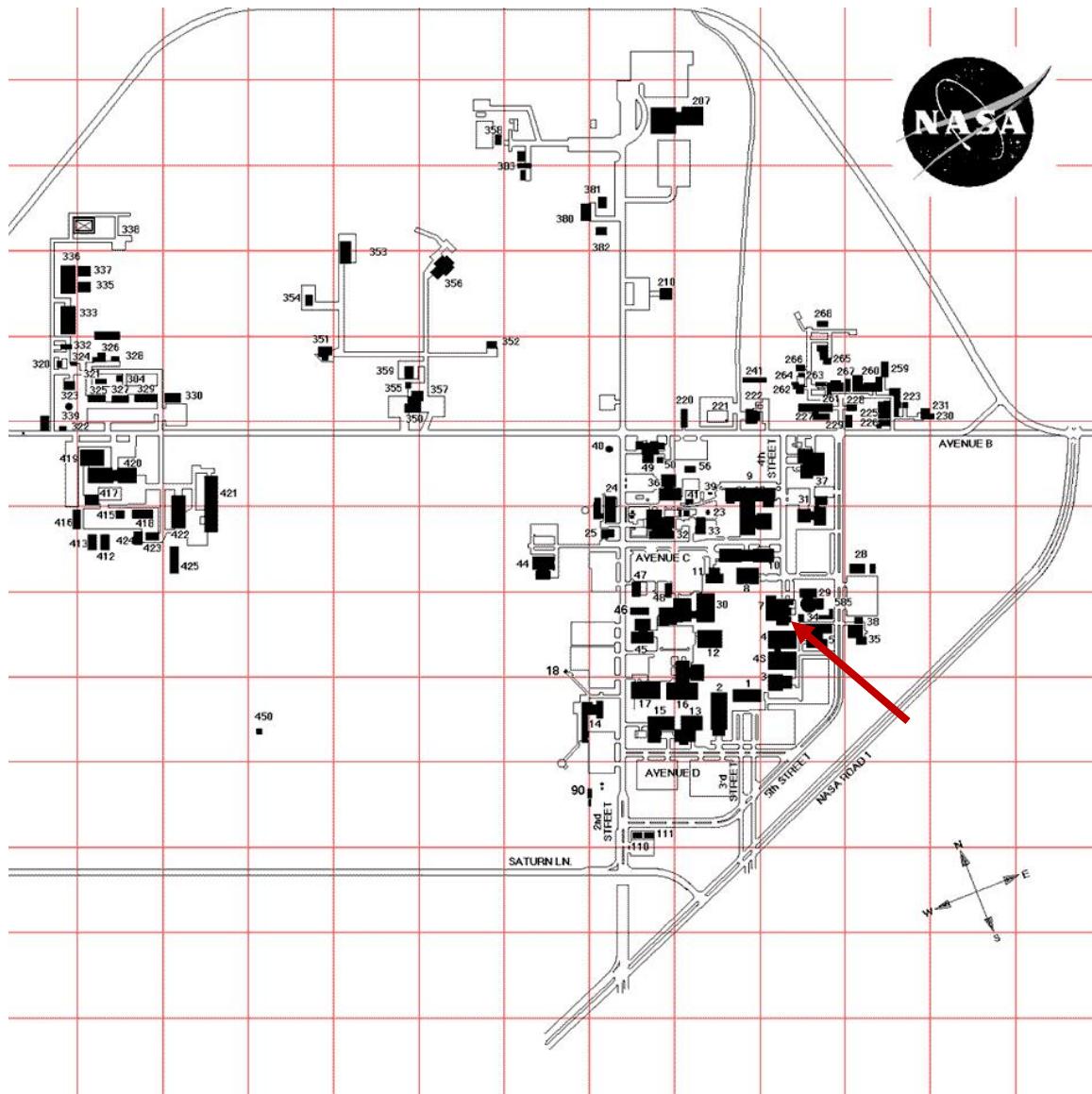


Figure 1. Location of the Crew Systems Laboratory.
Source: JSC, 2006.

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Photographs CSL-1 through CSL-79 were taken by Trish Slovinac, ACI; November 2009. Historic photographs (CSL-80 through CSL-96) are courtesy of the NASA JSC Imaging Center (Building 424), Houston, Texas, unless otherwise noted; the negative number is given in parentheses.

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NASA, Lyndon B. Johnson Space Center, Texas
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CSL-2



CSL-3



CSL-4



CSL-5



CSL-6



CSL-7



CSL -8



CSL -9



CSL -10



CSL -11



CSL -12



CSL -13



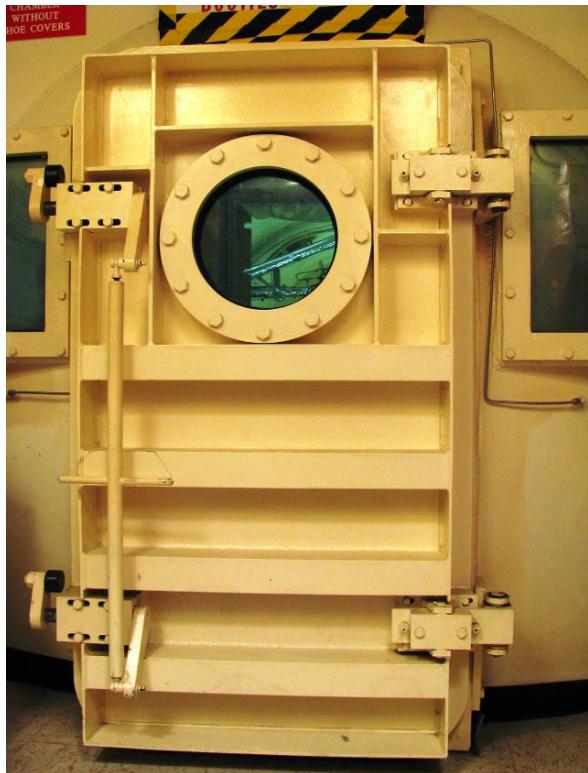
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CSL -18



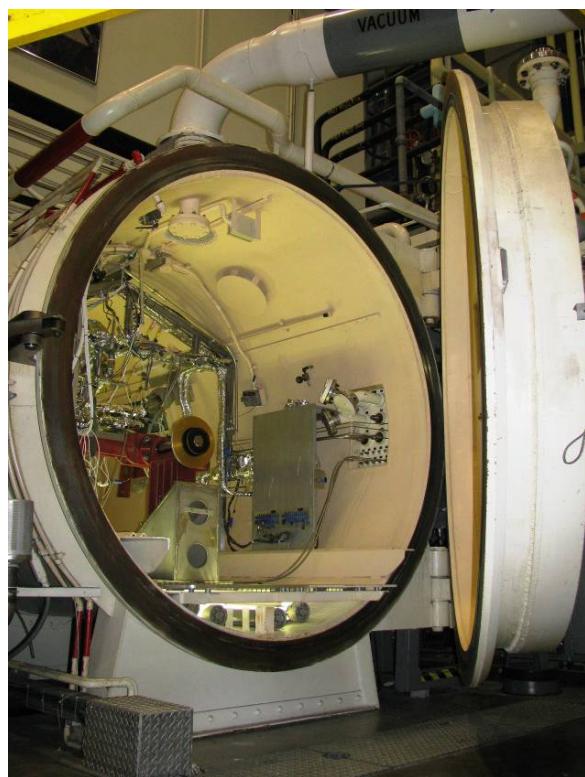
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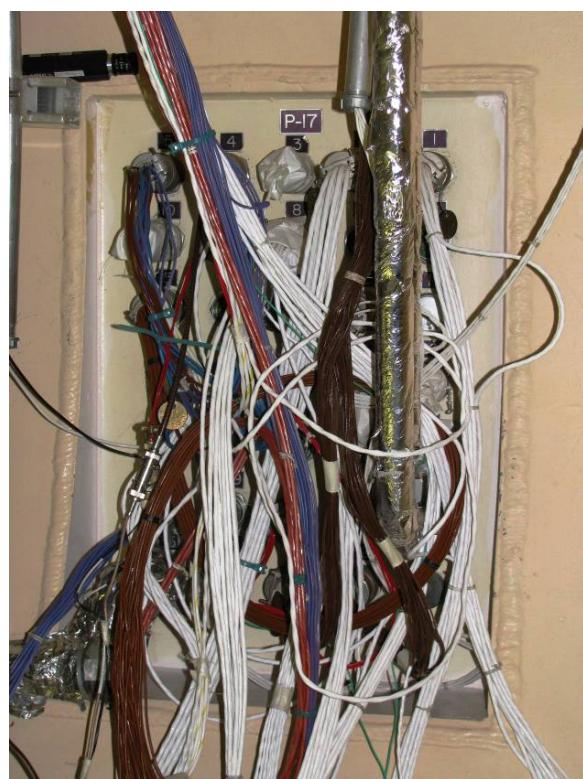
CSL -21



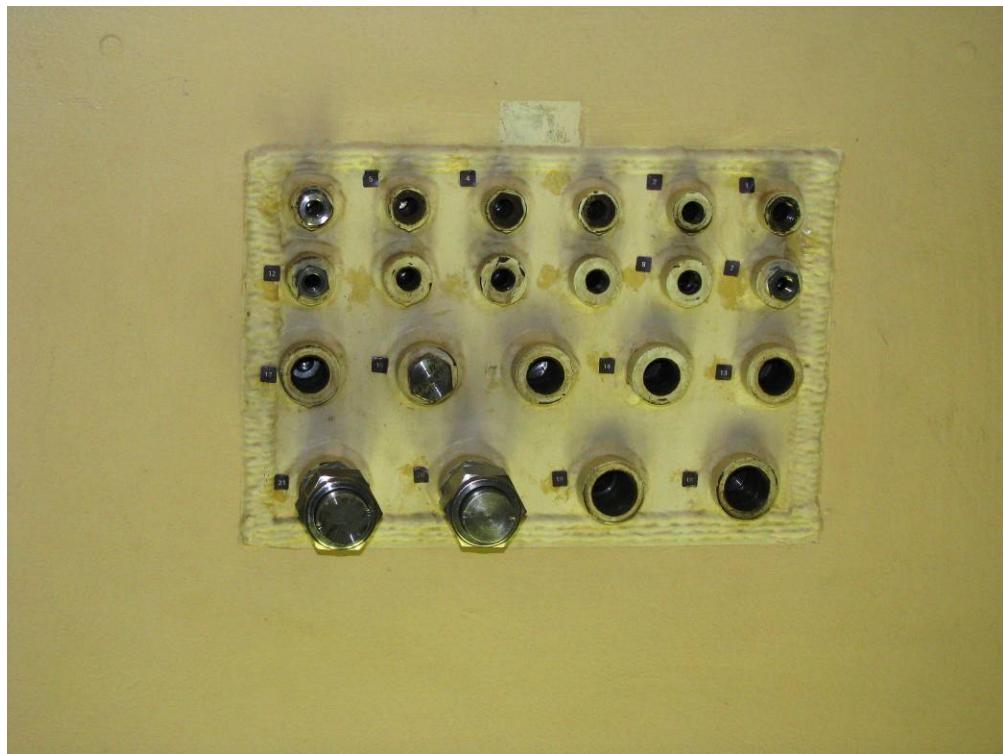
CSL -22



CSL -23



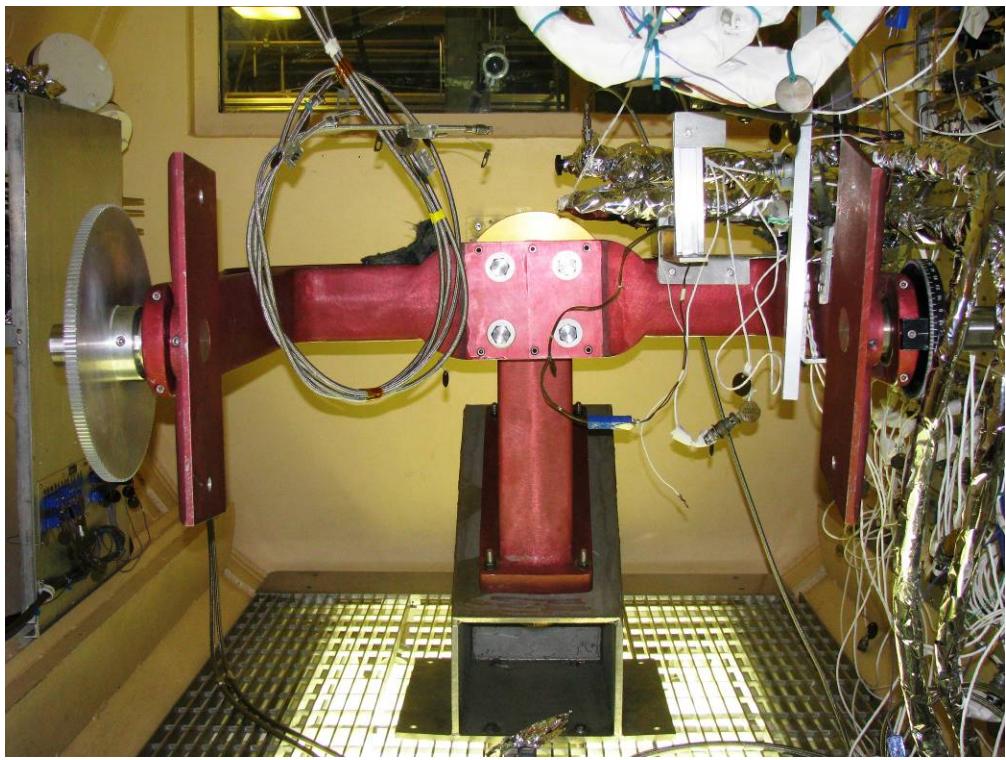
CSL -24



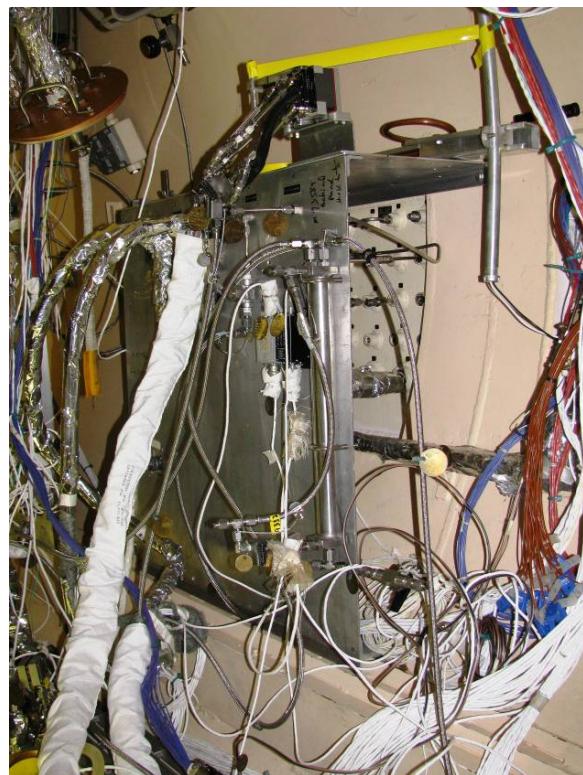
CSL -25



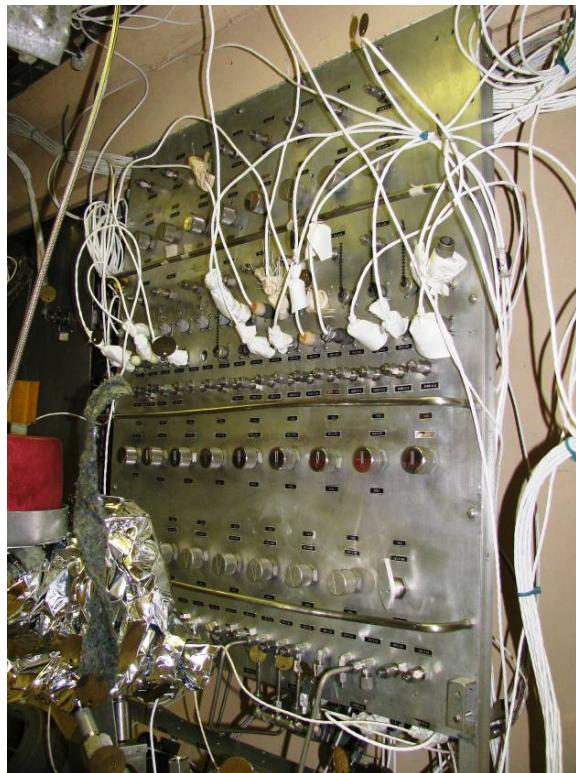
CSL -26



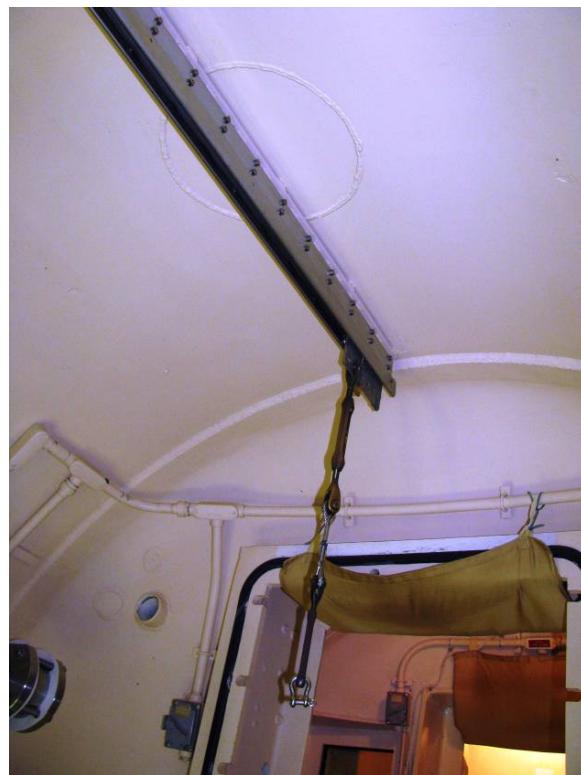
CSL -27



CSL -28



CSL -29



CSL -30



CSL -31



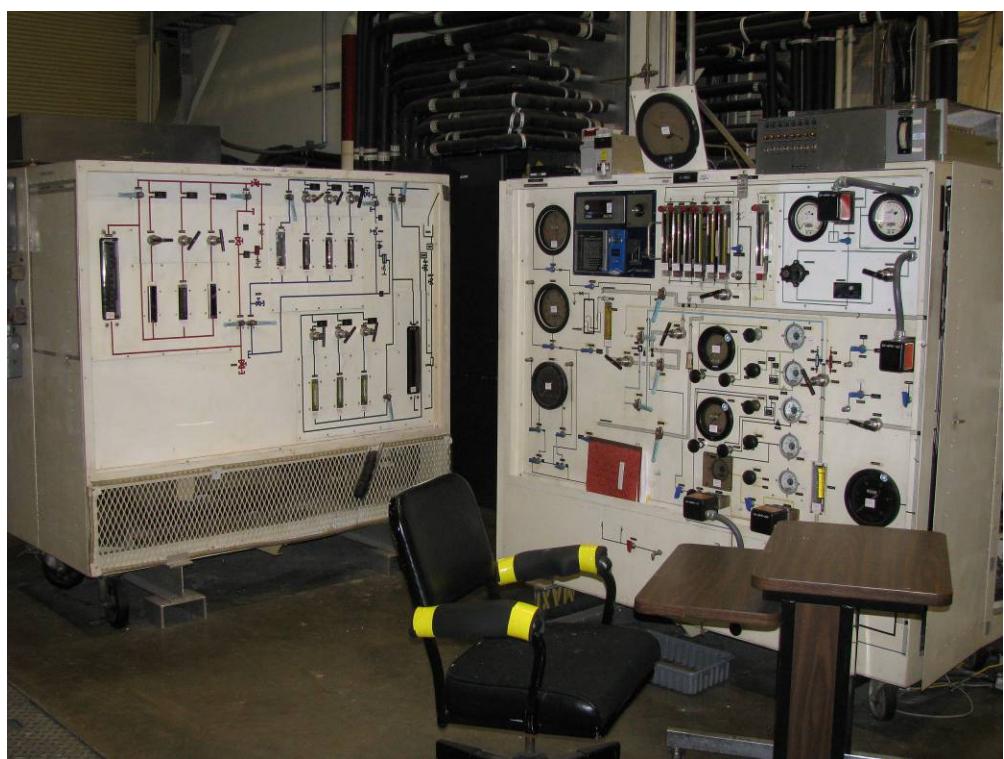
CSL -32



CSL -33



CSL -34



CSL -35



CSL -36



CSL -37



CSL -38



CSL -39



CSL -40



CSL -41



CSL -42



CSL -43



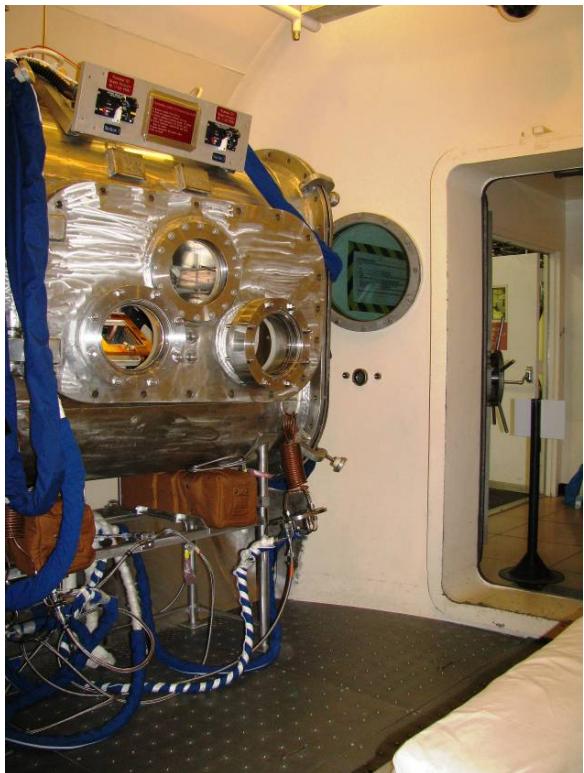
CSL -44



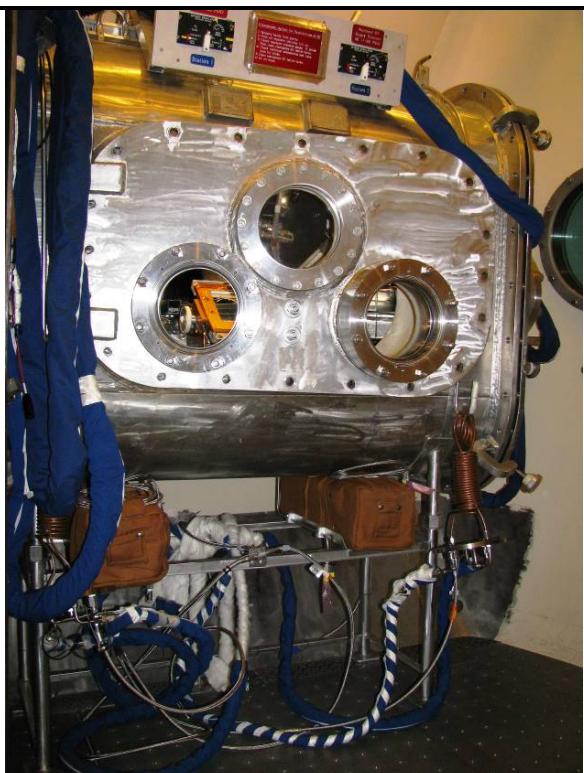
CSL -45



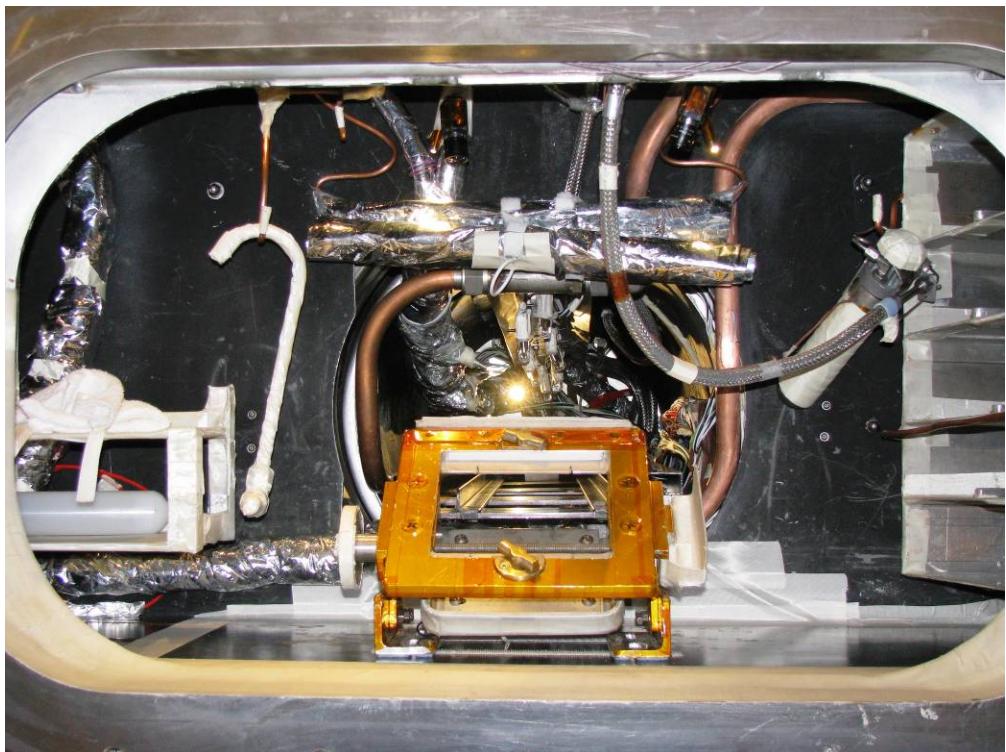
CSL -46



CSL -47



CSL -48



CSL -49



CSL -50



CSL -51



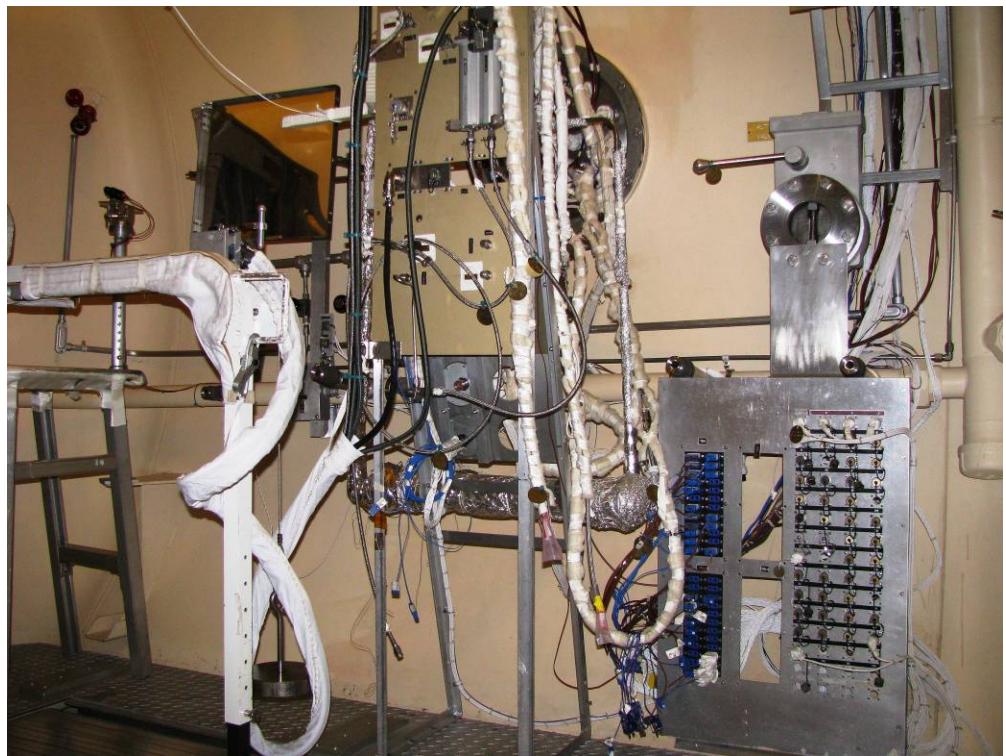
CSL -52



CSL -53



CSL -54



CSL -55



CSL -56



CSL -57



CSL -58



CSL -59



CSL -60



CSL -61



CSL -62



CSL -63



CSL -64



CSL -65



CSL -66



CSL -67



CSL -68



CSL -69



CSL -70



CSL -71



CSL -72



CSL -73



CSL -74



CSL -75



CSL -76



CSL -77



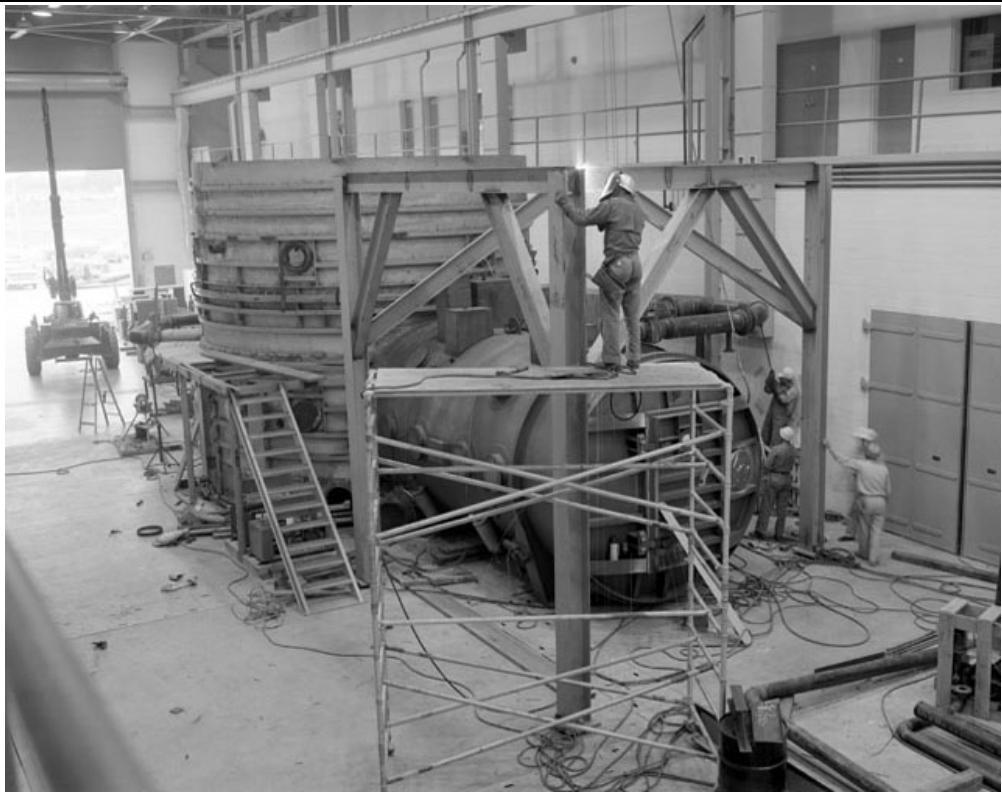
CSL -78



CSL -79



CSL -80



CSL -81



CSL -82



CSL -83



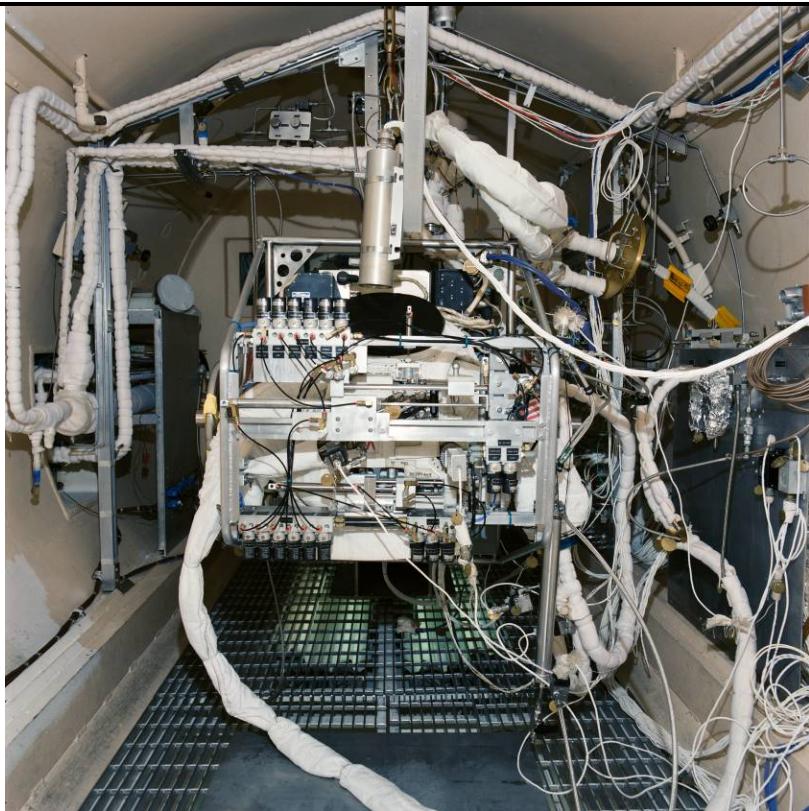
CSL -84



CSL -85



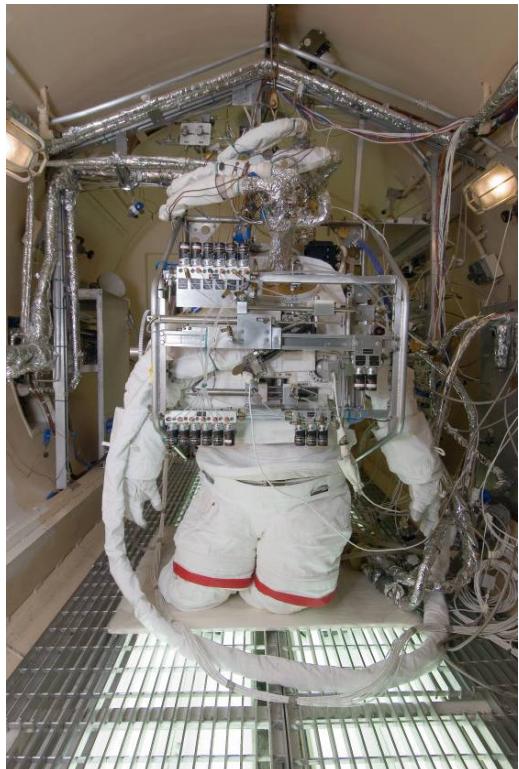
CSL -86



CSL -87



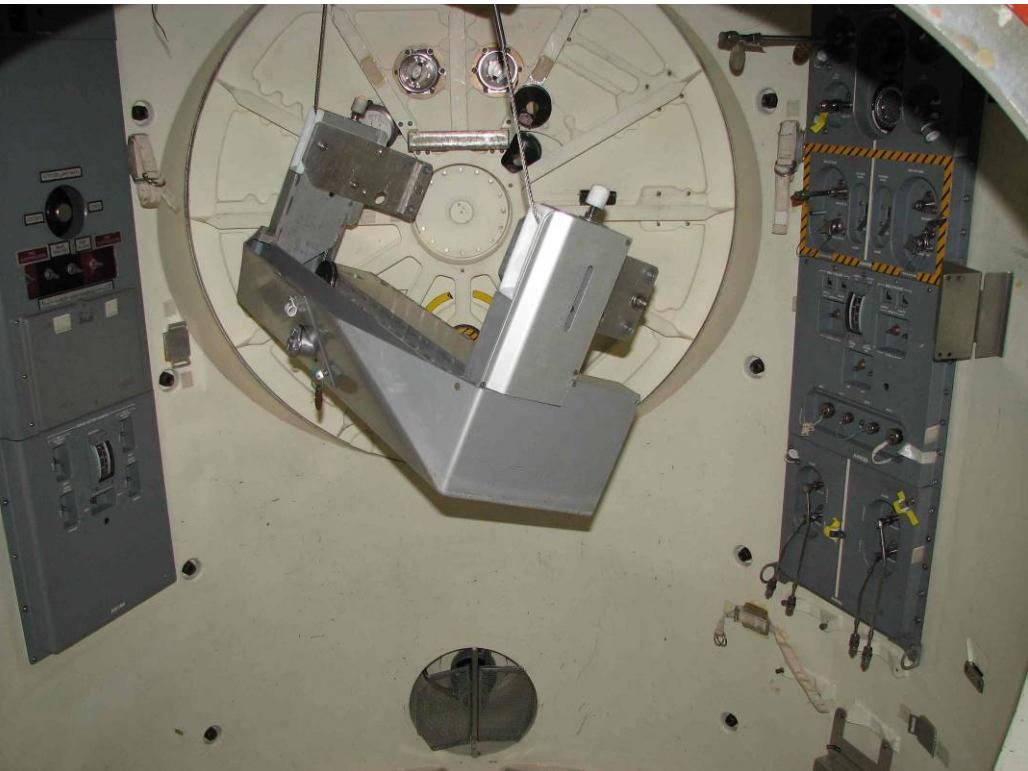
CSL -88



CSL -89



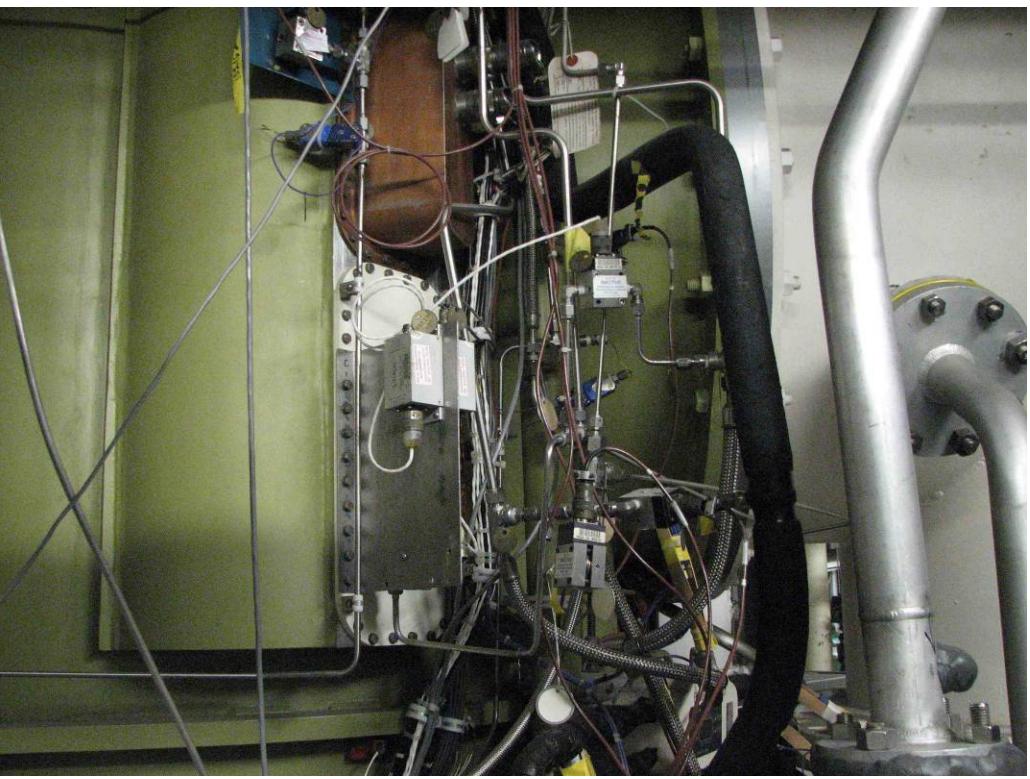
CSL -90



CSL -91



CSL -92



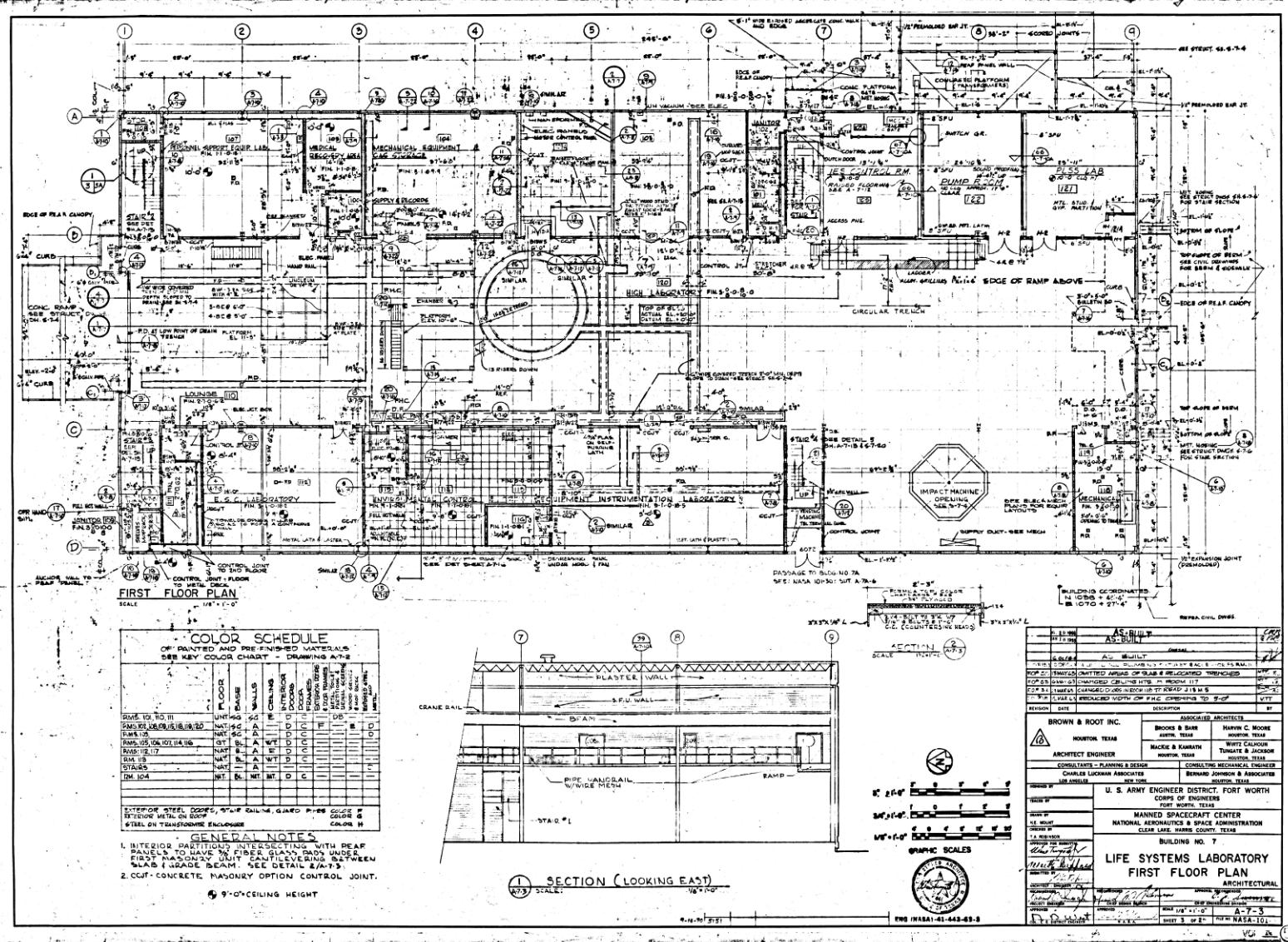
CSL -93



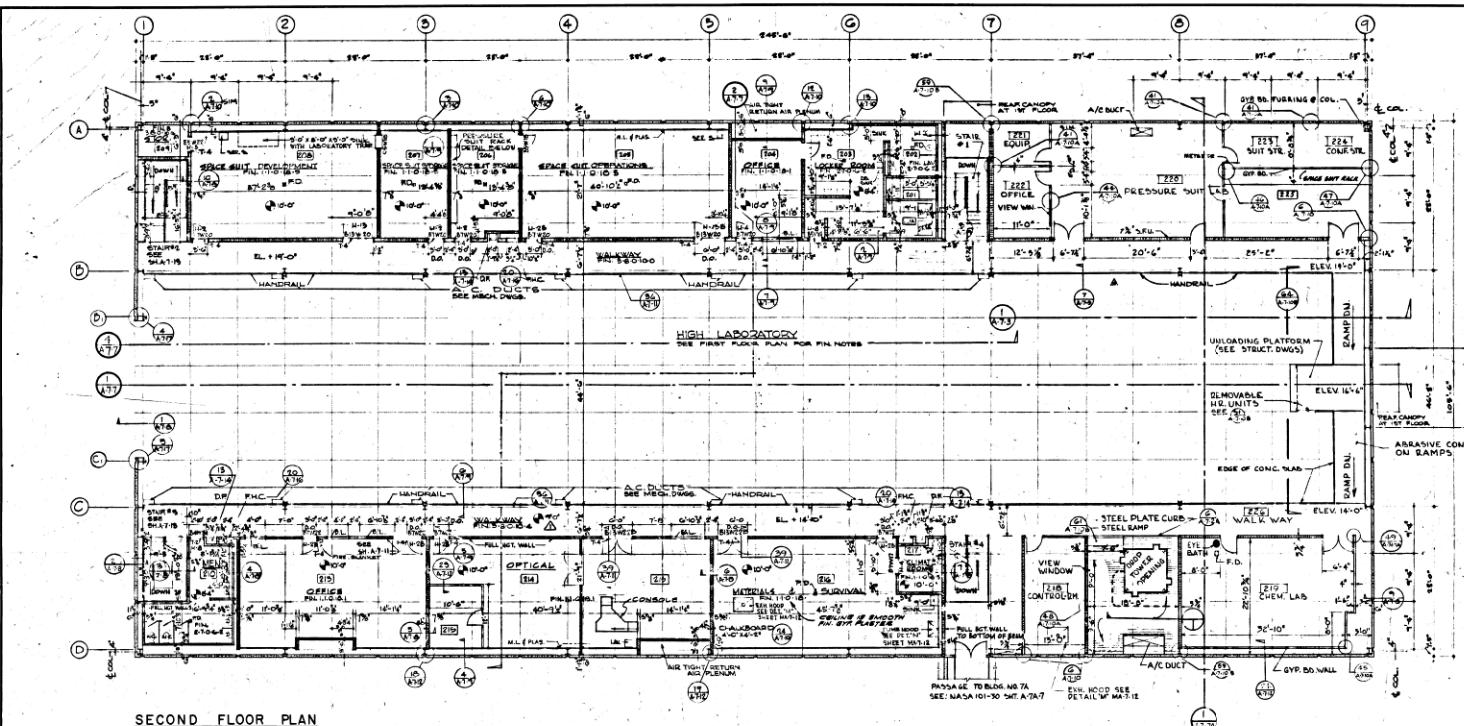
CSL -94



CSL -95



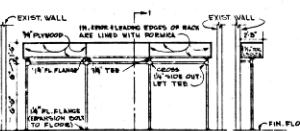
CSL-96



SECOND FLOOR PLAN

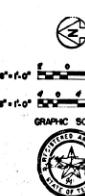
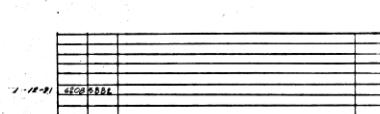
SCALE 1/8"

COLOR SCHEDULE									
OF PAINTED AND PFD-FINISHED MATERIALS									
SEE KEY COLOR CHART - DRAWING A-2									
	FLOOR	BASIS	WALLS	CEILING	DOORS	PORCH	STAIRS	ROOF	WALL
WALKWAYS	NAT	55	A	A	D				
BALCONIES	NAT	55	A	A	D				
OFFICES	GT	BL	A	WT	D				
TOILETS, LOCKER, SHOWER	UNG	50	66	E	D				
SUITE SLT ROOMS	ST	BL	A	A	D				
CLOSET, BATH, AMEN.	GT	BL	A	WT	D				
SUPPORT & RESTRAINT	GT	BL	A	WT	D				
MATERIALS & SURVIVAL	GT	BL	A	WT	D				
MEETING ROOM	GT	BL	A	WT	D				
HIGH LABORATORY	SHE	BP	BL	DO	DA	SCHEDULE	D		
STORAGE	UNG	50							



PRESSURE SUIT RACK ELEV. SECT. I-I

SCALE $\frac{1}{4}$ " = 1'-0"

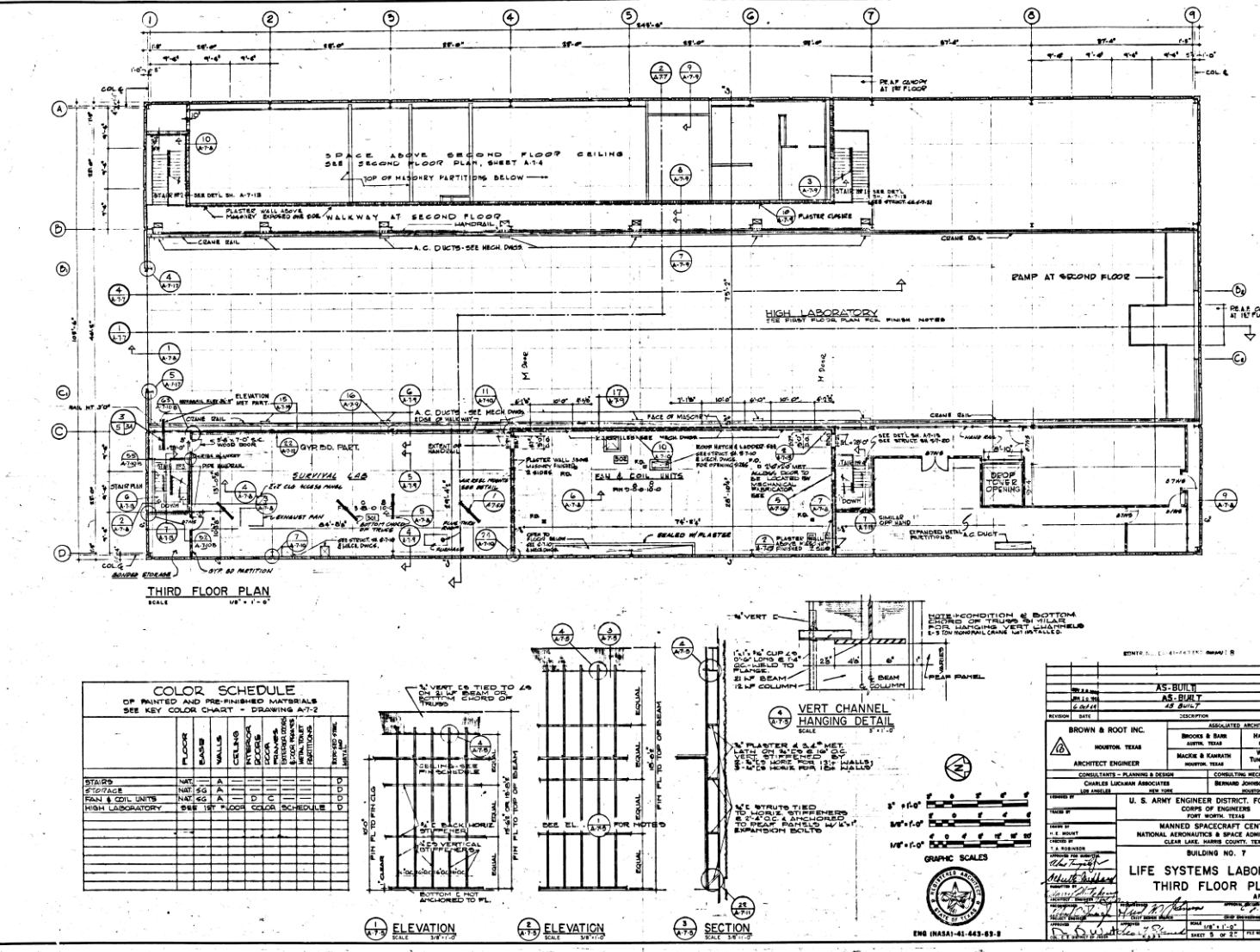


200-11000-11-000-00

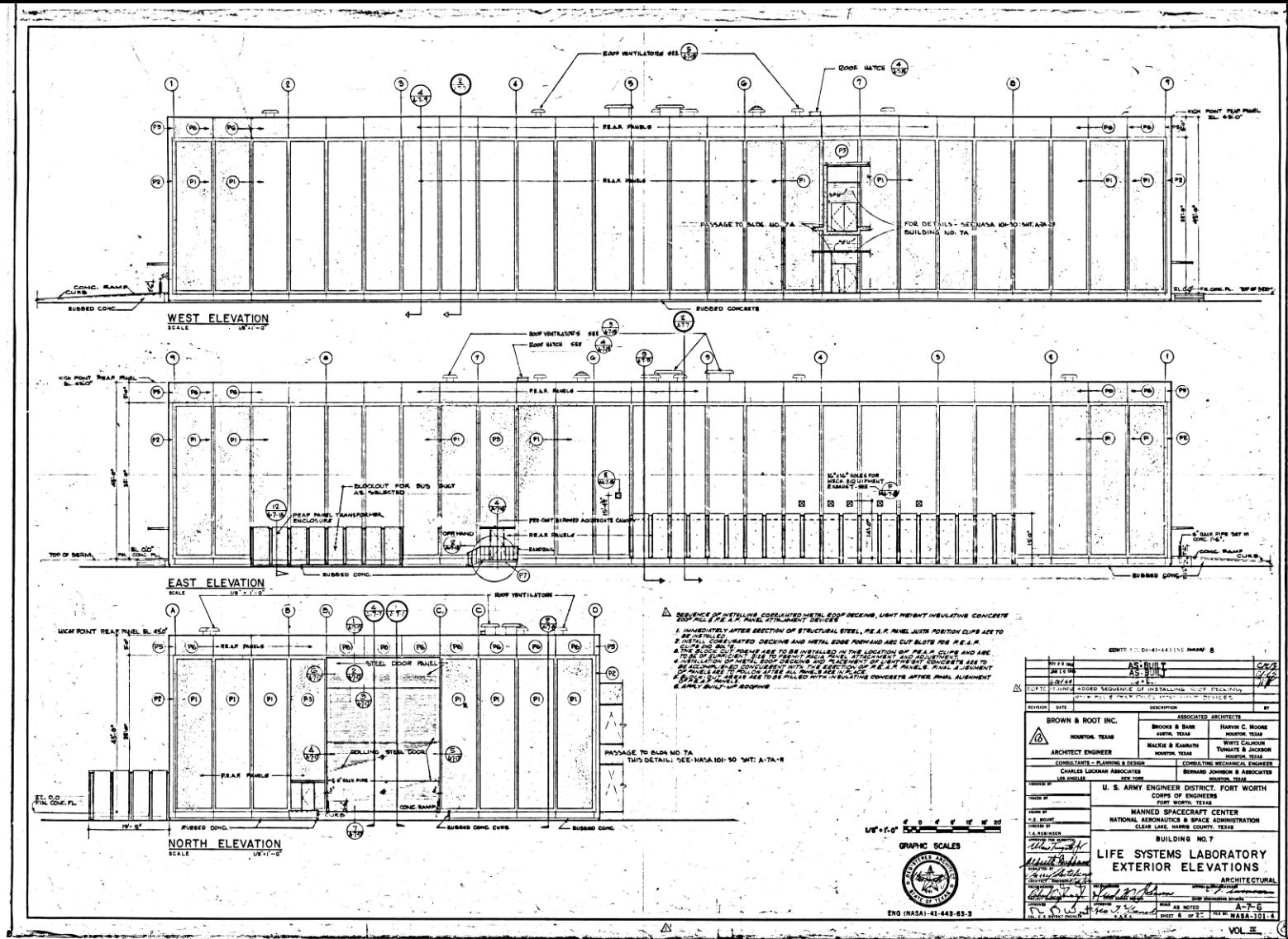
LIFE SYSTEMS LABORATORY
SECOND FLOOR PLAN

ARCHITECTURAL

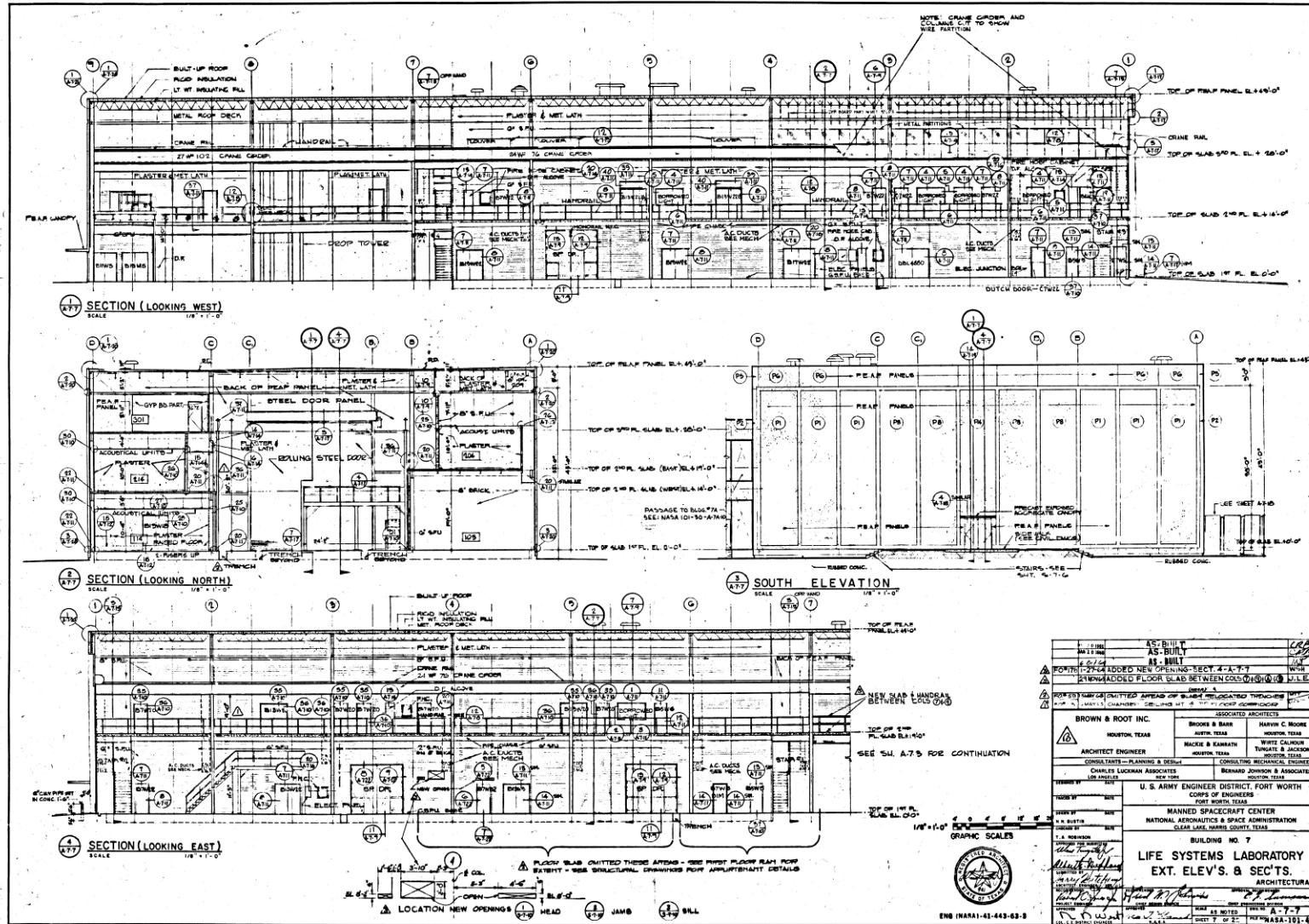
CSL-97



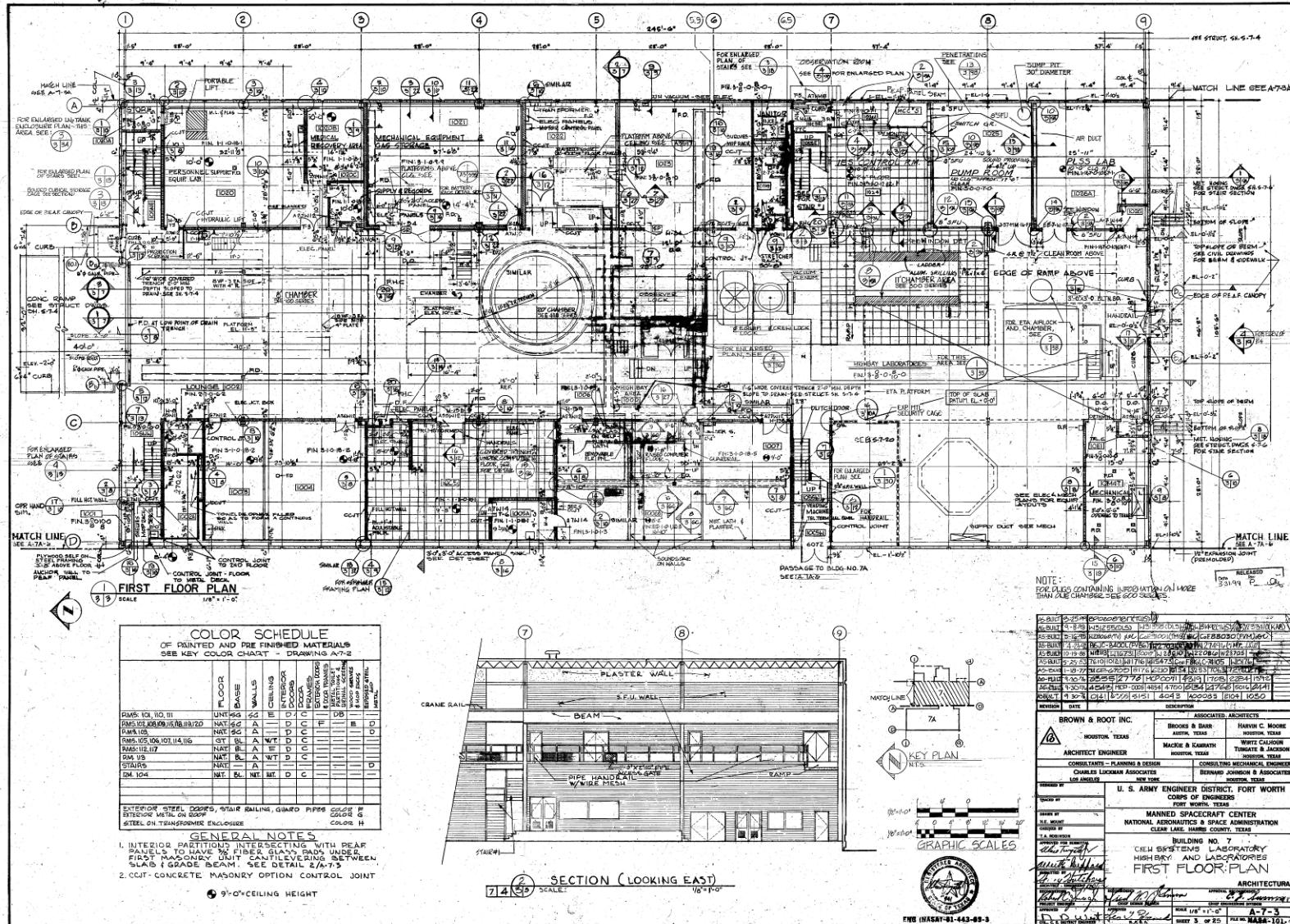
CSL-98



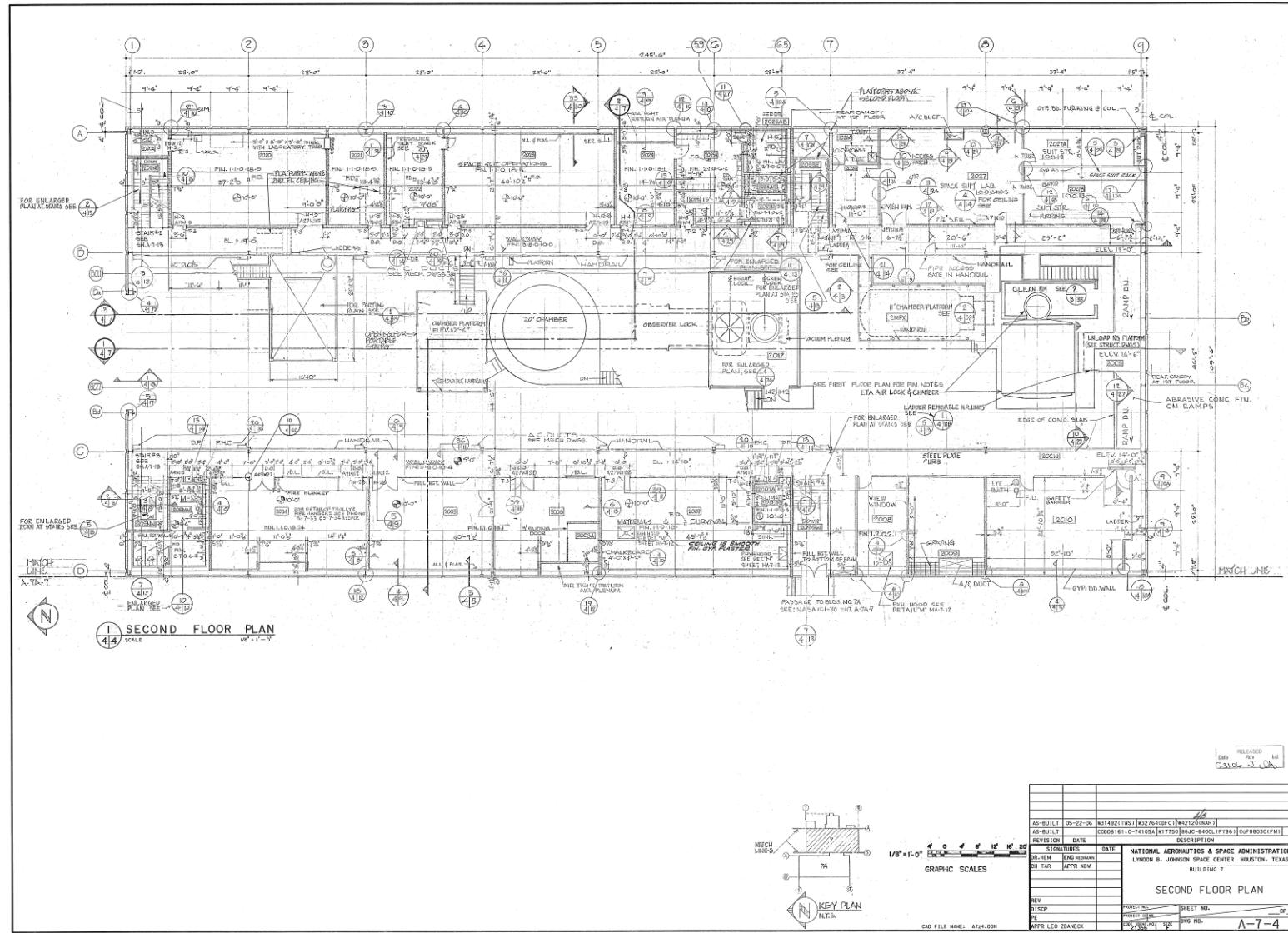
CSL-99



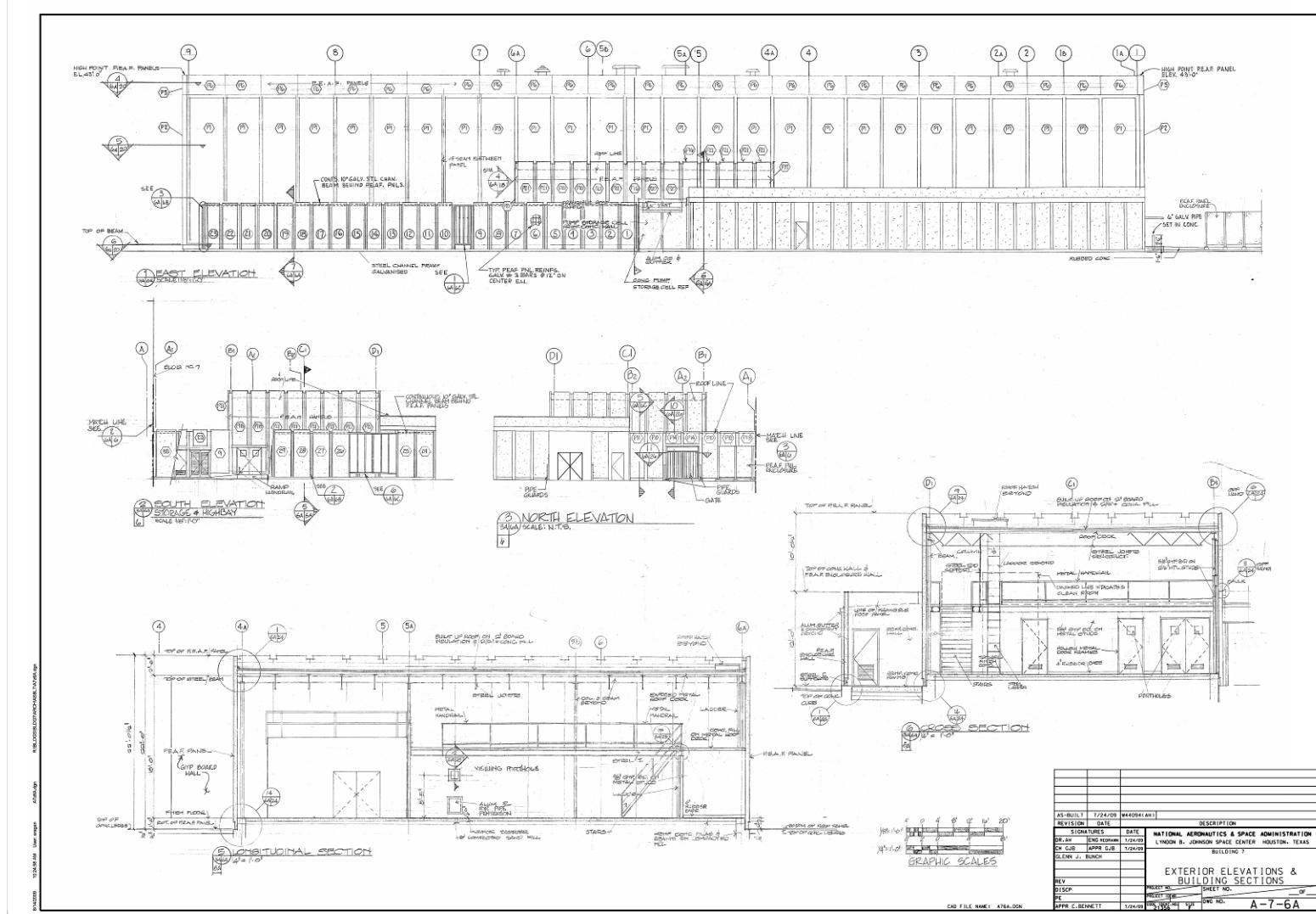
CSL-100



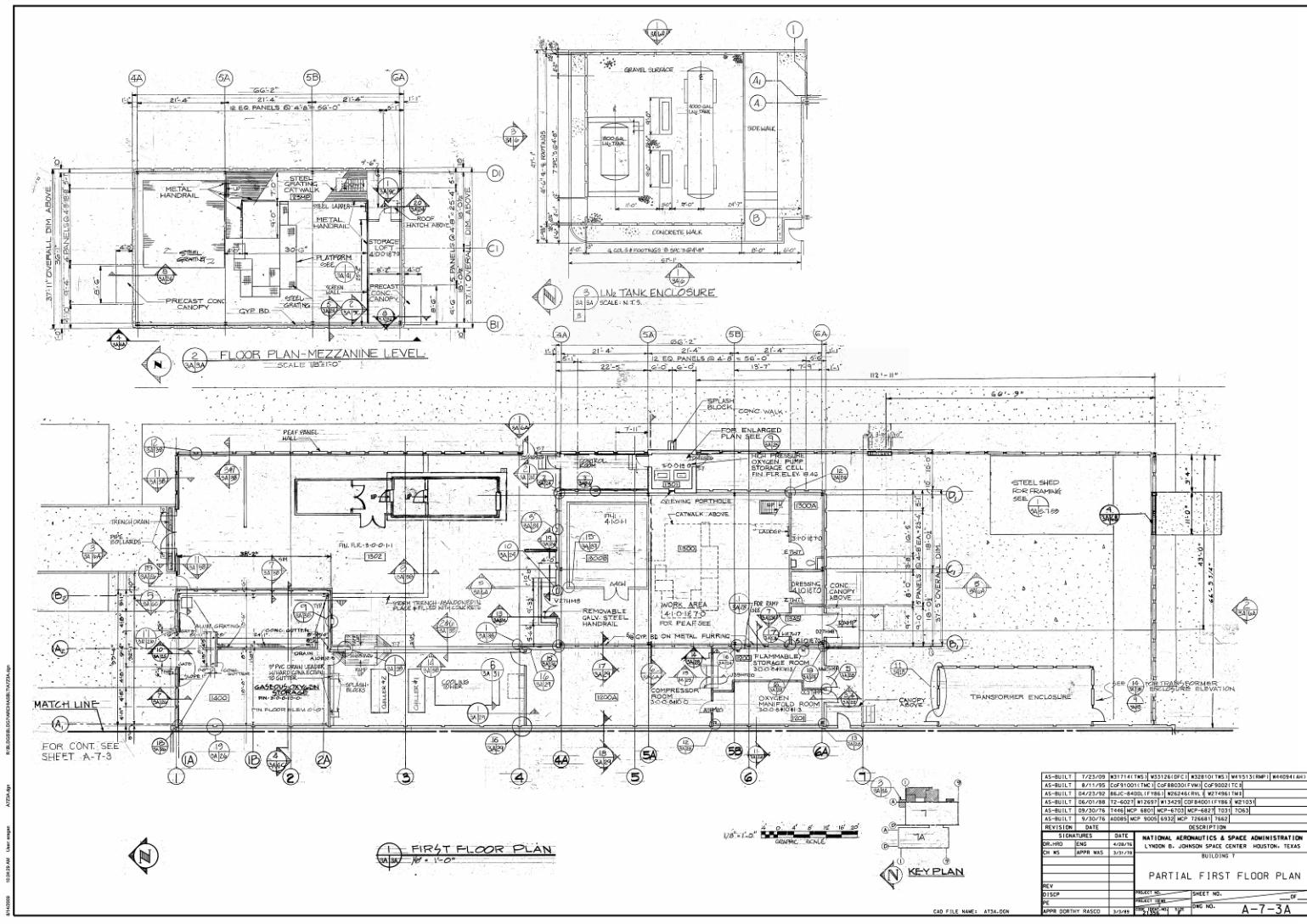
CSL-101



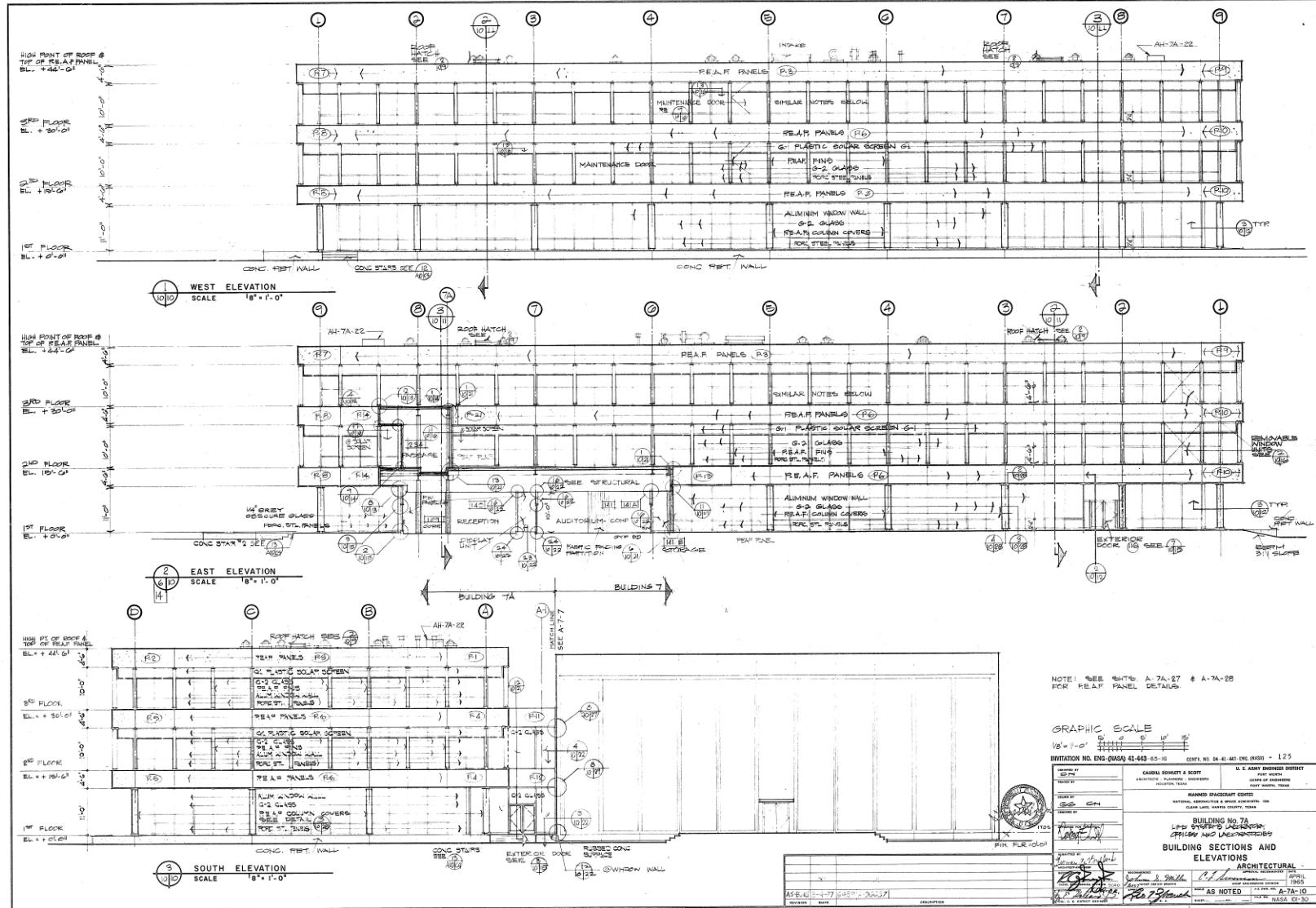
CSL-102



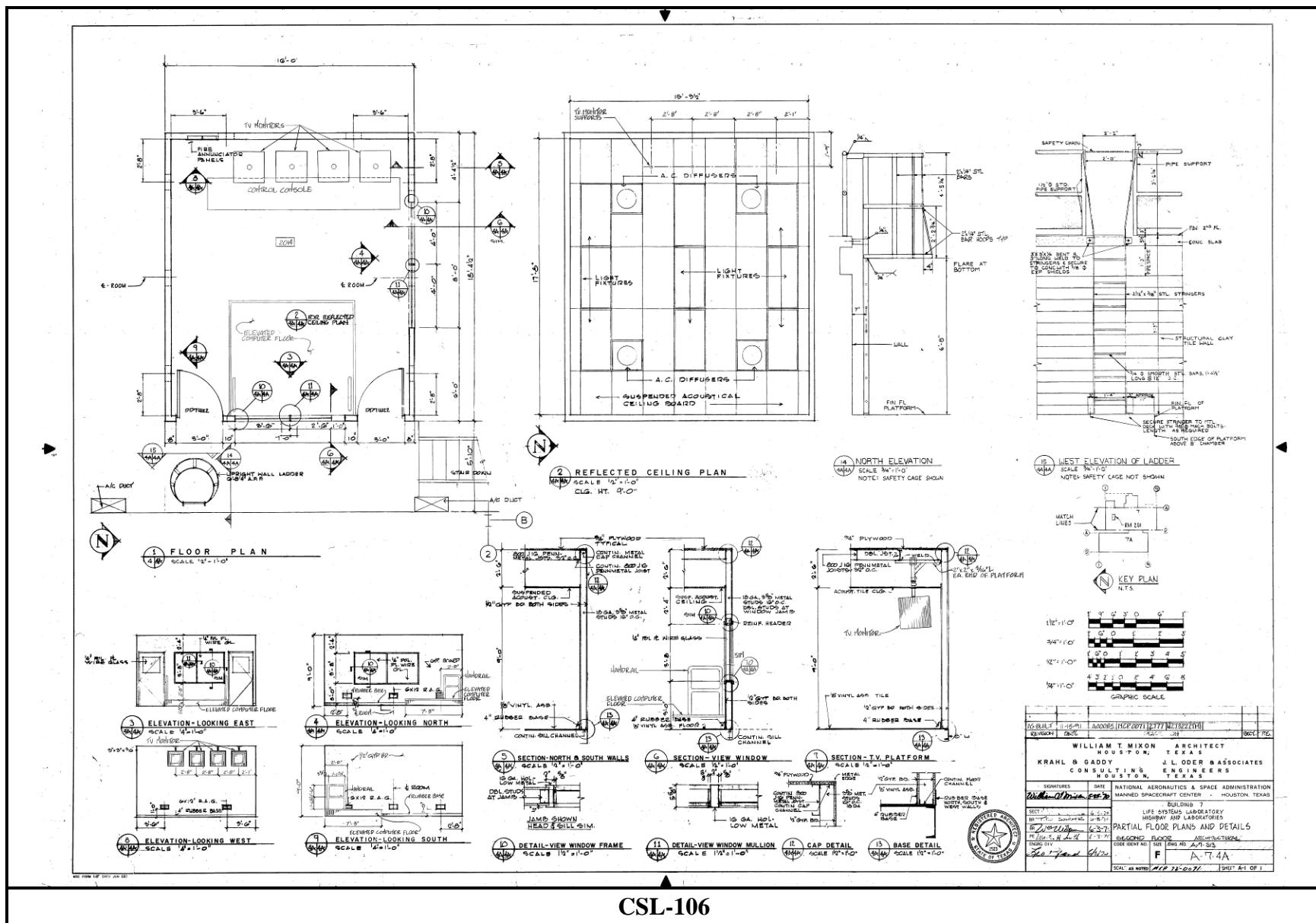
CSL-103

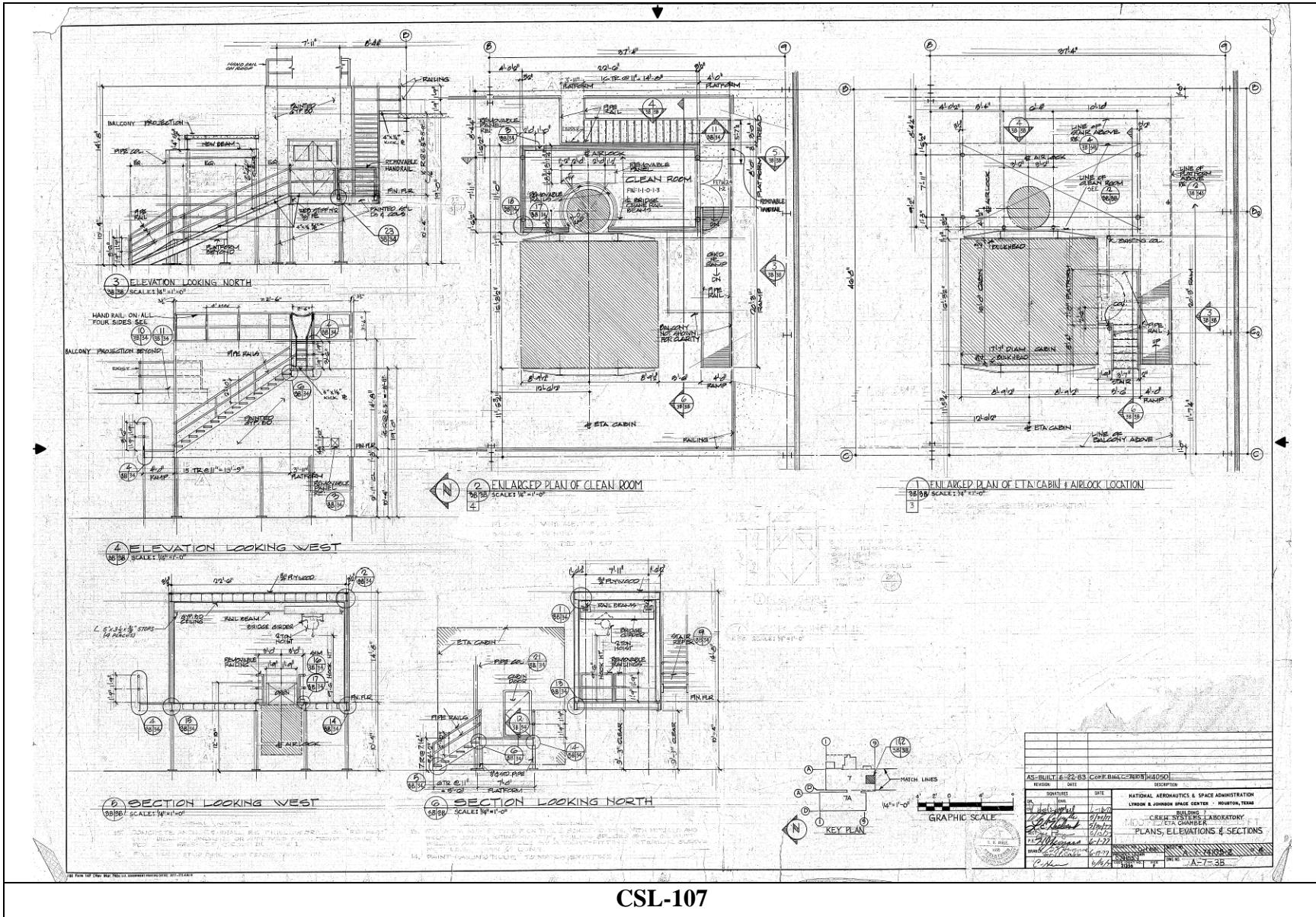


CSL-104



CSL-105





CSL-107